International Journal of Soft Computing 12 (1): 50-58, 2017
ISSN: 1816-9503

Genetic Algorithm (GA) and Ant Colony Optimization (ACO) Based Hybrid Technique for Solving Transmission Congestion Problem in Deregulated Power System

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Abstract: In this study, an integrated technique for solving congestion problem in deregulated power system is proposed. The proposed integrated technique is a hybrid combination of Genetic Algorithm (GA) and Ant Colony Optimization (ACO) algorithm first in class. The GA is one of the global optimization algorithms which generates best solution to optimization problems. In this study, Genetic Algorithm (GA) is used to optimize the real power changes of the generators from the generation limits while congestion occurred. The Ant Colony Algorithm (ACO) is one of the probabilistic based local search algorithm for solving computational problems which can be reduced to find good paths through graphs. In this study, the Ant Colony Algorithm (ACO) is used to minimize the congestion cost optimally by optimizing the incremental, decremented active power and the corresponding generator price bids. The proposed integrated technique is tested in IEEE standard 30 bus system to prove its robustness. The proposed technique effectively reduces the congestion management cost and the power loss of the system considered. The proposed integrated technique is implemented in MATLAB software and the output is compared with genetic algorithm.

Key words: Transmission congestion, power loss congestion removal, minimizing cost, hybrid technique, genetic algorithm, ant colony algorithm

INTRODUCTION

Restructuring and deregulation of electricity markets have huge after-effect on almost all electric power systems throughout the world (Ushasurendra and Parathasarthy, 2012). The restructuring of power system results in competitive electric market. In the present competitive scenario, electric companies utilizes the transmission system to its maximum capacity as construction of new transmission corridors is not as straight forward as in centrally planned systems (Elango and Sharmeela, 2011). It becomes more complex in transferring the desired transactions as there are more limitations in utilizing transmission systems and also the fact that supply and demand must be in balance at all times (Abedinia *et al*., 2012). The constraints on transmission system demand the specific amount of power that can be transferred between two nodes in the electrical network (Yousefi *et al*., 2012). It may not be possible to accomplish all transactions as it may lead to violation of operating constraints such as voltage limits and line flow limits. The existence of such network or transmission limitation is referred as congestion. Congestion or overload in one or more transmission lines may occur due to absence of coordination between generation and transmission companies or as a result of outages, it could make the fulfilling of existing contracts impossible, increases the prices in some areas of power systems and affects the system parts (Dehghan and Mirzaei, 2011). It can be said that, under congested conditions the price of transferring electricity will be increased (Sridevi *et al*., 2012a, b).

Independent System Operator (ISO) monitors and maintains the reliability of the power system in deregulated environment. During congested condition ISO adapts two types of techniques to relieve congestion and keeps the power system under stable condition. Cost free means non-cost-free means technique (Vergnol *et al*., 2009). The cost free means includes removing of congested lines or changing the transformer taps, phase shifters or FACTS (Flexible Alternating Current Transformation System) devices (Saini and Saxena, 2010). These are denoted as cost-free as the cost involved in their usage is limited. The non-cost-free means include Rescheduling of participating generator real power and reduction of loads and the methods of load interruption options (Elango and Sharmeela, 2011; Ushasurendra and Parathasarthy, 2012). Cost free means are more feasible in solving congestion problems from the economical grounds, so GENCO and DISCO will not be involved (Elango and Sharmeela, 2012).

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Many techniques are employed in relieving the congestion in modern power system. Congestion is relieved by placing the FACTS devices optimally with different methods based on static or dynamic performance of the system (Sakthivel *et al*., 2012). Overload sensitivity factor (power flow index) is used to identify the optimal location of series FACTS devices for static congestion management (Rajalakshmi *et al*., 2011; Sen *et al*., 2011). Evolutionary Algorithms (EAs) like Evolutionary Programming (EP), Genetic Algorithm (GA), Differential (DE) and Particle Swarm Optimization (PSO) are widely exploited during last two decades in the field of engineering optimization (Siddiqui *et al*., 2011; Sandip and Abhinandan, 2011). The congestion management is an comprehensive as well as particular defined way of improving electric power transfer in which power systems planning and operating can be considered (Iranmanesh and Nejad, 2012; Ramachandran and Sakthivel, 2012). In this study, a hybrid integrated technique is used for solving the transmission congestion problems first of type in the deregulated power system. Genetic Algorithm (GA) and Ant colony algorithm are utilized for solving congestion.

MATERIALS AND METHODS

Recent research works (a brief review): A brief study of research work carried out in recent years about managing congestion is discussed in this study. In most cases, the independent system operator removes congestion by rescheduling the real power of the generator. It is very difficult to meet all the power transactions in competitive electric market as in most of the case the transmission line is overloaded. A new transmission congestion distribution factor corresponding to real power flow of the line is proposed to detect the congestion clusters. The Independent System Operator (ISO) identifies the most sensitive generators to be rescheduled by using the sensitive congestion clusters (Sridevi *et al*., 2012a, b).

Congestion is also relieved by using Flexible Alternating Current Transmission (FACTS) devices. Different types of facts devices are used in relieving congestion. New concept of identifying an optimal location for placement of IPFC using different evolutionary algorithm is proposed. Optimal placement of IPFC with PSO algorithm and with genetic algorithm is proposed to effectively remove congestion (Masoud *et al*., 2012).

The multi objective Fuzzy Evolutionary Programming (FEP) and non dominated sorting genetic algorithm II methods are combined to remove congestion problem or over loading of transmission line. Here the fuzzy evolutionary programming uses the combined advantages of fuzzy and Evolutionary Programming (EP) to give more unique solution (Vijayakumar, 2012).

The optimal rescheduling of real power based on the sensitivity of the congested line by Fuzzy Adaptive Bacterial Foraging (FABF) method is proposed to reduce congestion. In this method, the generators to be participated in rescheduling are identified based on their sensitivity to the congested line and optimal rescheduling of real power is done by Fuzzy Adaptive Bacterial Foraging (FABF) method. The proposed method is tested on IEEE 30 bus system and Indian 75 test system and the results were compared with Particle Swarm Optimization (PSO) and simulated annealing method to prove the robustness and effectiveness of congestion management (Venkaiah and Kumar, 2011).

A new congestion management framework considering the dynamic voltage stability boundary of power system is proposed for solving congestion. A new précised dynamic model of power system equipment including the generators and loads were considered for solving congestion. The proposed method relieves congestion with lower cost and enhanced voltage stability margin. This method proves to be more advantageous than the previous congestion methods (Amjady and Hakimi, 2012).

The transmission congestion problem with the inclusion of voltage stability and the load ability limit is proposed. In this study, initially the base case economic load dispatch values are obtained to ensure the loading limits of generators and these results are used for rescheduling the generator real power output during congestion management. The optimal rescheduling is obtained for three block bid structure submitted to Independent System Operator (ISO) in a day ahead market. The three block bid structure is modeled as a function of up and down rescheduling of real power of generator within the limits offered for congestion management. The third generation FACTS devices are also utilized for optimal rescheduling of generators in the proposed method for managing congestion.

Congestion problem is managed in a restructured electricity market by combining Demand Response (DR) and Flexible Alternating Current Transmission (FACTS) devices. Initially generation companies submit bids to market to achieve maximum profit. The Independent System Operator (ISO) decides the market clearing price based on social welfare. The Independent System Operator (ISO) also decides the network constraints for congestion problem. Secondly, a mixed integer optimization technique is proposed to relieve congestion by optimally coordinating the facts devices and Demand Response (DR) with generators (Yousefi *et al*., 2012).

A new method is introduced for optimal sizing and location of multi type distributed generators to reduce the power losses of the system. These papers explains the reduction of cost of energy losses and the total power losses by optimizing the real power of the system (Mahdad and Srairi, 2016). A meta heuristic based new approach is proposed in solving congestion problem. The proposed method uses firefly algorithm to reschedule the active power of the generators to remove congestion with less congestion cost (Verma and Mukherjee, 2016). Multi line congestion problem is solved by a hybrid nelder-mead-fuzzy adaptive particle swarm optimization. In this study multi line congestion is solved by using a new novel apparent power sensitivity factor method to reschedule the generator real power (Nesamalar *et al*., 2016).

Problem description: In the modern deregulated power system, transmission congestion is a multi objective problem. Congestion occurs in a transmission line if the line is overloaded or the physical limit of the transmission line is exceeded. In this study, congestion problem is considered as a non-convex optimization problem as it has more number of equal and in equal constraints. Such non-convex optimization problems can't be solved directly by mathematical methods. Most of the conventional methods suffer from local optimal conditions. These reasons restrict the traditional methods to solve small real time problems. Thus, a global and local search algorithm is required which must effectively solve the congestion problem. Genetic algorithm is a good population based global search algorithm for solving wide optimization problems. Ant colony algorithm is local search algorithm for solving local search problems. Therefore, in this study an hybrid global and local search algorithm of genetic algorithm and ant colony algorithm is introduced first in type. Congestion problem is also related to optimal power flow problem. So, optimal power flow formulation is necessary for minimizing the fuel cost. Therefore, rescheduling of real power is based on meeting the system load requirements, operating constraints and line flow limits.

Congestion management: In a deregulated power system environment, the significant role of independent system operator is to maintain the power system stability and solidity while deciding the cost-effective decisions on market participants. The power balance condition of the system for bilateral and multi lateral power transactions between the buyer bus j and seller bus i is modeled as follows bilateral power transaction:

$$P_{G_i} - P_{D_j} = 0 \quad (1)$$

Multi lateral power transaction:

$$\sum_{i \in N_g} P_{G_i} - \sum_{j \in N_l} P_{D_j} = 0 \quad (2)$$

Where:

P_{gi} = The amount of active power injected at seller bus i
P_{dj} = The amount of active power captivated at buyer bus j, respectively

To examine the credibility left without any changes on network limitations, the transactions are proposed by various participants to system operator. If there are any violations in the transactions of the participants, then a suitable congestion management scheme should be employed to operate the system in safe condition. In this study, the feasible rescheduling of active power generation from the preferred schedule is considered to reduce the congestion. The incremental and decremented generator price bidding costs are offered by each and every generating unit to the system operator. This price bids helps in estimating the minimum cost required to relieve congestion, referred to congestion cost. The mathematical expression of congestion management cost is described by Joshi and Pandya (2011), minimize total congestion cost:

$$TCC = \sum_{i=1}^{N_g} C_i^+ \Delta P_i^+ + \sum_{i=1}^{N_g} C_i^- \Delta P_i^- \quad (3)$$

Where:

C^+_i and C^-_i = The additive and decremented cost-coefficients of the ith generator
ΔP^+_i and ΔP^-_i = The variations in generator power from favored schedule in incrementing or decrementing side at ith generator

Hence, the system operator always ensures the system stability and reliability by employing this type of power rescheduling techniques.

Formulation of optimal power flow problem: Here, the real power outputs from the generating units can be approximated quadratic function (Leeton and Kulworawanichpong, 2011). The objective function in terms of the production cost is symbolically represented as follows Minimize:

$$Fuel_t^{cost} = \sum_{i=1}^{N_g} f_i(P_i) \quad (4)$$

Where:

$$f_i(P_i) = a_i P_i^2 + b_i P_i + c_i$$

Where:

$i = 1, 2, 3, ..., N_G$	= The expression for cost function corresponding to ith generating unit
a_i-c_i	= Its cost coefficients
P_i	= The real power output (MW) of ith generator
N_G	= The number of generating units

Depending upon assumptions and practical implications, the constrained OPF problem is subjected. Also, it consist of power balance constraints to obtain the energy balance, feasible real power, reactive power generation, voltage constraints at load buses and line flow limits. The constraints are represented in the following study.

Constraints of power balance: The power balance constraints of the system depend on the equality constraints between total generation and total demand of the system. The power balance conditions are represented in terms of nonlinear power flow equations which are represented as:

$$P_{G_i} = P_{D_i} + \sum_{j=1}^{n} |V_i||V_j||Y_{ij}|\cos(\theta_{ij} - \delta_i + \delta_j) \quad (5)$$

$$Q_{G_i} = Q_{D_i} + \sum_{j=1}^{n} |V_i||V_j||Y_{ij}|\sin(\theta_{ij} - \delta_i + \delta_j) \quad (6)$$

Where:

P_{Gi} Q_{Gi}, P_{di} and Q_{di}	= The real-power and reactive power injected at ith bus and the corresponding load demand, respectively
Y_{ij} and θ_{ij}	= The admittance matrix and voltage angle between ith and jth buses
V_i, V_j, δ_i and δ_j	= The magnitude and angle of bus ith and jth, respectively

Then, the real power loss of the system is modeled as:

$$P_{loss} = \sum_{k=1}^{N_L} G_k \left[|V_i|^2 + |V_j|^2 - 2|V_i||V_j|\cos(\delta_i - \delta_j) \right] \quad (7)$$

where, G_k is the conductance of transmission line which is connected between ith and jth buses.

Generator power constraints and voltage limits: The generation limits of generators are divided in to upper and lower bound which lies in between actual limits. Then, the voltage magnitudes of the each load buses after performing the load flow analysis should be confirmed between its bound. This voltage magnitude is having its own lower and upper bound and mathematically represented as Eq. 10. The real, reactive power and voltage inequality constraints are described as:

$$P_{G_i}^{min} \le P_{G_i} \le P_{G_i}^{max} \quad (8)$$

$$Q_{G_i}^{min} \le Q_{G_i} \le Q_{G_i}^{max} \quad (9)$$

$$V_i^{min} \le V_i \le V_i^{max} \quad (10)$$

Where:

P_{Gi}^{min} and P_{Gi}^{max}	= The negative and positive bounds of active power of ith generators
Q_{Gi}^{min} and Q_{Gi}^{max}	= The negative and positive bounds of reactive power of ith generator unit
V_i^{min} and V_i^{max}	= The voltage limits of ith bus

In this study, the GA is used to determine the exact generation limits for removing the transmission congestion. The purpose of ACO is to minimize the congestion management cost. The detail explanation of GA and ACO algorithm are described in the following study.

Optimal congestion removal generation limit determined by Genetic Algorithm (GA): GA is one of the evolutionary algorithm based artificial intelligence technique. It is global search optimization algorithms based on the process of natural selection and genetics. They operate on chromosomes, typically listing of binary digits representing a coding of the control parameters of the given optimization problem. These chromosomes comprises of particular group of genes. In this study, the purpose of genetic algorithm is used to optimize the incremental and decremented real power of generator for removing the transmission congestion of the system. It requires one evaluation function called as fitness function to assign the quality value to every solution produced. Here, the favored real power of the generator is rescheduled optimally to reduce power losses of the congestion.

For selecting the best generation power values, it has five steps which are categorized as chromosome generation, evaluation of fitness function, crossover, mutation and termination. The detailed description of GA for proposed technique is discussed.

Generate chromosomes: The first step of the GA is chromosome generation. In the steps, the chromosomes are generated randomly with the bounded limits. In the study, the numbers of generator bus (P_{Gi}) of the power system are selected as the number of chromosomes. Then, the genes of the chromosomes are considered as the range of the generation limits ($P_{Gi}^{min} \le P_{Gi} \le P_{Gi}^{max}$). Similarly,

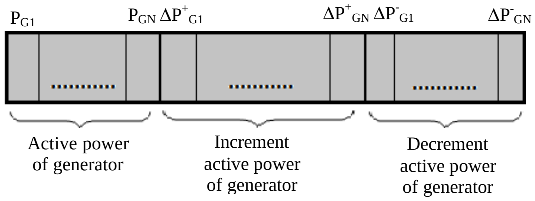

Fig. 1: The simple structure of chromosomes

the chromosomes of increment active power (P^+_{GN}) and decrement active power (P^-_{GN}) are generated. The chromosomes structure which used for proposed approach is shwon in Fig. 1.

Evaluation of fitness function: The fitness function evaluation is the second step of GA. It is a type of objective function which is used to digest as how close a given design solution is to achieve the set aims. The fitness function of the proposed technique is calculated by Eq. 12:

$$\text{Fitness function} = \min\left(P_{loss}(n)\right) \tag{11}$$

where, $P_{loss}(n)$ is the power loss of nth bus of the system.

Crossover: Crossover is an extremely important operator of GA. The crossover operation recombines the structure of mating chromosomes. The chromosomes of the two parents selected are united to shape new chromosomes that inherit segments of information stored in parent chromosomes. Many crossover schemes such as single point, multipoint or uniform crossover have been used in literature till now. Then, the crossover rate (C_r) is calculated that is defined as the ratio of number of genes crossovered and length of chromosomes.

Mutation: Mutation is one of the genetic operators that is responsible for the insertion of new information. By a small probability, random bits of the offspring chromosomes turn over vice versa and give new characteristics. In the study, the mutation operation is applied to provide best solution. Then, the mutation rate is calculated by the ratio of mutation point and chromosome length.

Termination: The final step of GA is termination. In this step, the best solutions are generated at maximum iteration. Among the generated solution, the active power limit that provides less power losses are selected to the next processes.

RESULTS AND DISCUSSION

Basic concepts of ACO: Ants establish a shortest route from their colonies to the food source for feeding. It is the natural behavior of real ants that lives in community. While a secluded ant travels fundamentally at arbitrary, an ant identifies the formerly laid pheromone substance and decides to move alongside the pheromone substance at higher probability, thus assisting through the trail path with its previously laid pheromone substance (Dorigo and Gambardella, 1997). According to pheromone evaporation ants can easily identify the essence on precised route against the longest path and thus chooses the precised path to reach the destination quickly. In this study, ACO algorithm is used for minimizing the congestion management cost. The detailed description of ACO algorithm to the introduced approach is discussed in the following study.

Mathematical formulation of ACO algorithm: The ACO algorithm is one of the very fast searching algorithms which depend on the metaheuristic mathematical formulation. The mathematical equations are formulated depending on the state transition rules and pheromone updating rules. The mathematical equation of state transition and pheromone update are expressed as follows.

State transition rule: The state transition rule of ACO is known as proportional pseudo-random rule. In this study, the feasible solution is obtained by removing congestion at the affected buses, without violating any limits of the power system. The state transition rule is described as:

$$x = \begin{cases} \underset{(i,\, j)\in B_k}{\arg\max}\left\{\left[\tau(i,\, j)\right]\left[\eta(i,\, j)\right]^{\beta}\right\} & \text{if } q \le q_0 \\ X & \text{Otherwise} \end{cases} \tag{12}$$

Where:

- x = The division (i, j) to obtain a support as per the solutions given by the function arg max or the arbitrary variable X
- $\tau(j, i)$ = The pheromone trail laid in-between the buses i and j, respectively
- $\eta(i, j)$ = The value of the heuristic-function placed across the branches i and j, respectively
- β = Represents the significance of the heuristic-function, arg max selects the highest value for the result $[\tau(i, j)][\eta(i, j)]^\beta$
- B_k = The number of branches that has not attained the highest number of reinforcements allowed
- q = The randomized number to follow a consistent allocation U (0, 1)
- q_0 = A flexible parameter ($0 \le q_0 \le 1$)
- X = Corresponds to variable that follows an isolated distribution given by Eq. 13 which described as follows

$$g_k(i,j) = \begin{cases} \dfrac{[\tau(i,j)][\eta(i,j)]^\beta}{\sum_{(t,u)\in B_k} \{[\tau(t,u)][\eta(t,u)]^\beta\}}, & \text{if } (i,j)\in B_k \\ 0, & \text{Otherwise} \end{cases} \quad (13)$$

Pheromone updating rules: The pheromone update rules play a major role in understanding the concepts of ant colony searching algorithm. In this algorithm, the combination of numerical values with pheromone trails laid on the branches represents the need of an intensified search in accordance with the existing solution. The pheromones are updated by local and global updating rules in ACO algorithm. The pheromone values are updated at each time when an ant chooses a branch for reinforcement by local updation rules represented by:

$$\tau(i,j) = (1-\phi)\tau(i,j) + \phi\tau_0 \quad (14)$$

Where:

φ = The local pheromone decrease rate

τ_0 = The pheromone trail for all branches at the beginning of reproduction process

When the ants completes the search, the global pheromone update is applied. Global pheromone is updated by either iteration best or best thus far strategies. The global updating rule is expressed as:

$$\Delta\tau(i,j) = \begin{cases} \left(\dfrac{T_{pher}}{V^*}\right)\sqrt{P_{circ}}, & \text{if } (i,j)\in slop^* \\ 0, & \text{Otherwise} \end{cases} \quad (15)$$

Where:

T_{pher} = Adjust the pheromone trails that should be higher than every final solution-cost received during the first-expedition

V^* = The best possible value that relates to best solution

$slop^*$ = Previous-expedition

P_{cire} = Relates to number of paths added to the branch-(i, j)

$\Delta\tau(i, j)$ = The trail placed on the branch (i, j) denoted by $slop^*$. The new pheromone trail

$\tau(i, j)$ = Used in the updation is represented by

$$\begin{cases} \text{if } (i,j)\in slop^* \rightarrow \tau(i,j)^{new} = (1-\rho)\tau(i,j)^{old} + \rho\Delta\tau(i,j) \\ f(i,j)\notin slop^* \rightarrow \tau(i,j)^{new} = (1-\rho)\tau(i,j)^{old} + \rho\tau_0 \end{cases} \quad (16)$$

Where:

ρ = The learning rate of the algorithm in correspondence to pheromone-trails

τ (i, j) = The pheromone trails in the last global update

Then, the detailed explanation for reducing congestion cost is explained.

Steps of ACO algorithm:

(i) To minimize the congestion cost, the congestion is introduced into the transmission system randomly. The real power is rescheduled and the best incremental and decremented price bids are optimized by ACO algorithm. The load flow program is analyzed and congestion is removed. If a possible good solution is obtained, goto step (iv), otherwise go to step (ii)

(ii) The fitness function congestion cost is evaluated by Eq. 4. The proportional pseudo-random rules are applied, in accordance to (12) and (13) and reinforcement required is added to system. Go to step (iii).

(iii) Local updation rule is applied in accordance with (14), to the respective branch and power flow is employed. If the solution obtained is feasible, go to step (iv), else goto step (ii).

(iv) The solution is updated and the ant's mission is stopped. If the pre-accepted number of ants assignment (P_{cire}) within an expected value is reached the expedition is finished, go to step (v). Otherwise, new mission will be started, then, go back to step (i).

(v) The best solution is selected from all the missions of the final expedition and the global updation rule is applied in accordance with (15) and (16). If the highest maximum number of expected value (P_{cire}(max)) is obtained or if the best solution not enhanced after a pre-defined number of consecutive expeditions ($P_{cire} \leq P_{cire}$(max)), go to step (vi). Otherwise, start a new expedition, i.e., goto step (i).

(vi) The (P_{cire}(best)) best solutions established among all outings are finally selected.

RESULTS AND DISCUSSION

The proposed hybrid combination of genetic algorithm and ant colony algorithm is tested on IEEE 30 bus system using MATLAB to solve congestion problem and to minimize congestion cost. The proposed system consists of six generator buses, twenty four load buses and forty one transmission lines. The data's for solving congestion problem are found in http://www.ee. washington. edu/research/pstca. In this test system congestion is created by increasing the load of 1 MW in steps at load bus 3 up to 50 iterations, till some lines exceeds its line limits. An informal power flow of 144.5 MW is recorded in line 1 connected between bus 1 and bus 2 whose line limit is 130 MW. The details of congested line and the amount of power flow in the line are shown in Table 1.

Thus in the line between bus 1 and 2 the power is overloaded by 14.5 MW whose line limit is 130 MW. This overloading of transmission line is referred to as congestion. The congestion has to be relieved as soon as possible to maintain the stability of the system. In this study, congestion management problem is solved

Table 1: Congested line details of 30-bus system

Congested line	Power flow (MW)	Line limit (MW)
1-2	144.5	130

Table 2: Generation limits and bidding cost

	Generator limits		Bidding cost	
Generator No.	P_{min}	P_{max}	C^+_i	C^-_i
G_1	50	200	22	18
G_2	20	80	21	19
G_5	15	50	42	38
G_8	10	35	43	37
G_{11}	10	30	43	35
G_{13}	12	40	41	39

Table 3: GA parameters

Parameters	Values
No of population	100.00
Number of iterations	50.00
Cross over rate	0.30
Mutation rate	0.06

Table 4: Real power flow of congested line before and after congestion management

Real power flow		Real power (MW) flow before congestion management	Real power (MW) flow after congestion management (GA)
From bus	To bus		
1	2	144.5	130

Table 5: Favored generator bidding cost

	Favored bidding cost	
Generator No.	Incremental bidding cost	Decremented bidding cost
G_1	22-23	17-19
G_2	20-22	18-20
G_5	41-43	37-39
G_8	42-44	36-38
G_{11}	42-44	34-36
G_{13}	40-42	38-40

using two techniques. Firstly, the congestion is relieved by genetic algorithm and the congestion cost is calculated with respective generator bids. The generator data and the bidding cost values are shown in Table 2. The parameters used for implementing genetic algorithm are shown in Table 3.

The favored generation schedule matching the exact load conditions are obtained by genetic algorithm. Here all the generator outputs are considered as the variable for optimal rescheduling by genetic algorithm. Real powers of the generators before and after congestion management by using genetic algorithm are shown in Table 4.

Secondly, the hybrid combination of genetic algorithm and ant colony algorithm is performed for the same condition of the congested line. In this technique genetic algorithm is used to optimize the real power of the generators. The ant colony algorithm is used to reduce the congestion cost by randomly incrementing and decrementing the bidding cost without affecting the transactions made by the generation companies with the independent system operator to reduce the congestion cost of the system. The favored range of incremental and

Table 6: Parameters for Ant colony slgorithm

Parameters	Values
No. of ants	60
No. of iterations	25

Table 7: Real power flow of congested line before and after congestion management

Real power flow		Real power (MW) flow before congestion management	Real power (MW) flow after congestion management (Hybrid)
From bus	To bus		
1	2	144.5	129

Table 8: Comparison of real power flow of congested line before and after congestion management

Real power flow		Real power (MW) flow before congestion management	Real power (MW) after congestion flow management	
From bus	To bus		GA	Hybrid
1	2	144.5	130	129

Table 9: Congestion management cost and real power loss of the proposed technique

Congested line		Congestion management cost ($/h)	Real power loss (MW)	
From bus	To bus		Before	After
3	4	889	12.9	6.0
6	7	686	19.5	6.3
9	10	770	13.2	5.6
12	14	504	21.9	5.9
15	16	250	22.0	6.3
18	19	466	32.6	6.0

decremented bidding cost values for reducing congestion cost is shown in Table 5. The parameters used for ant colony algorithm for reducing the congestion cost are shown in Table 6. The real power before and after congestion management by hybrid genetic algorithm and ant colony algorithm is shown in Table 7. Solving congestion problem by the proposed hybrid technique proves to be more robust when compared to the genetic algorithm. The real power flow of the congested line is brought into the limit from 144.5-129 MW. Thus, the congestion is relieved from the system to ensure the stability of the system. The comparison of real power flow in the congested line before and after congestion management using GA and hybrid GA and ACO is shown in Table 8.

The congestion management cost for the proposed hybrid genetic and ant colony algorithm is shown in table 9.The real power losses of the different cases of congested line before congestion management is summarized in Table 9. By implementing the proposed technique the real power losses of the transmission line after congestion management is greatly reduced when compared to the genetic algorithm.

The rescheduling of generator real power by the genetic algorithm and the hybrid technique before and after congestion is summarized in Table 10. Before congesting the transmission line the normal system losses was 12.15 MW which seems to be quite high. The system

Table 10: Summary of real power

	Real power before congestion management		Real power after congestion management	
Generator No.	GA	Hybrid	GA	Hybrid
G_1	192	116	75	57
G_2	45	77	46	31
G_5	23	16	27	50
G_8	25	10	35	27
G_{11}	25	28	10	25
G_{13}	38	22	31	27

Table 11: System losses before congestion management

Normal system losses (MW)	System losses before congestion management by GA (MW)	System losses before congestion management by Hybrid (MW)
12.15	13.6	15.828

Table12: System losses after congestion management

Normal system losses (MW)	System losses after congestion management by GA (MW)	System losses after congestion management by Hybrid (MW)
12.15	7.8	5.35

Table 13: Comparison of congestion management cost

Congestion cost	GA $/Hr	Hybrid $/Hr
Best	1075.0	889.0
Worst	1077.2	890.2
Mean	1076.1	889.6

loss before congestion management by genetic algorithm was 13.6 MW and before congestion management by hybrid technique was 15.828 MW. The summary of the system losses before congestion management is shown in Table 11.

After relieving congestion by genetic algorithm in the transmission line, the system losses was reduced to 7.8 MW from 13.6 MW. The system losses was further reduced to 5.35 MW from 15.38 MW by the hybrid technique. The summary of the system losses after congestion management is shown in Table 12. The detailed summary of the congestion management cost by genetic algorithm and ant colony algorithm is shown in Table 13. The proposed method proves to be more promising and it greatly reduces the congestion management cost compared to genetic algorithm.

CONCLUSION

In this study, a new integrated hybrid technique for removing transmission congestion is proposed. The proposed hybrid technique is incorporated with GA and ACO algorithm. In the hybrid technique, the GA is used to generate optimal generator power for rescheduling the system. Then, the transmission line congestion problem is created randomly and is solved by the proposed approach. The purpose of ACO algorithm is to minimize the congestion management cost by select the best bidding cost. The methodology is analyzed with IEEE 30 bus system and is compared with GA based optimization approach. The convergence of the proposed hybrid technique shows the robustness of the technique. The proposed work can be extended to IEEE 57 and IEEE 118 bus system and the results can be compared in the extension work.

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