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A COMBINED CONGESTION MANAGEMENT TECHNIQUE FOR RESCHEDULING OF OPTIMAL ACTIVE POWER OF GENERATOR UNITS

N. CHIDAMBARARAJ[1], Dr. K. CHITRA[2]
[1]Research Scholar, Sathyabama University.
[2]Professor, Department of Electronics and Communication Engineering
VIT University, Chennai Campus, Chennai, India.
E-mail: [1]chidambararaj1281@gmail.com

ABSTRACT

In paper, a combined technique proposed for solving transmission congestion problem in deregulated power system. For improving the congestion management performance of cuckoo search (CS) algorithm, the artificial neural network (ANN) is combined with CS algorithm. Here, the CS is optimized the real power changes of the generator while transmission congestion is occurred. Thus, the ANN is used to predict the generator reschedule real power according to the transmission congestion. Hence, the computational performance of CS algorithm is enhanced. Then, the congestion management cost and power loss of the proposed method is minimized by the CS algorithm according to the transmission congestion. Proposed method is implemented in MATLAB working platform and the real power rescheduling, congest management cost, and power loss are evaluated. The congestion management performance of the proposed method (ANN-CS) is compared with CS and PSO algorithm.

Keywords: *Transmission Congestion, Real Power, Reschedule, Combined Algorithm, ANN-CS Algorithm, Cost, Power Loss.*

1. INTRODUCTION

Today, most of power system operators seek to apply their systems as competently as feasible and near to their load ability limits due to high development costs of power systems [1], stable increase in power demand, environmental and monetary limits [2], weak deliver of reactive power [3], rise in the share of dynamic loads with nonlinear characteristics and at last huge amount of dealings which have made vivid transforms in load flow in deregulated electricity markets [4]. There is a larger focus on managing network benefits competently rather than strengthening the network's capacity [5] with the opening of deregulation in electric power industry. In addition, the transmission open contact and maximum profit environment force the operation of power systems to be nearer to their limits [6]. Power systems often encounter congestion problem in such states. Due to destruction in power system operating limits [7] [8], Congestion in a viable electricity market happens when the transmission network is not capable to put up all of the preferred transactions.

The congestion administration is one of the main missions of the ISO and uses market based approaches in viable markets for improving congestion [9]. Based on locational marginal prices, price area zones, and economic transmission rights, generation rescheduling [10] [11], the market based approaches can be classified. Redispatching based systems, restriction of preferred schedules beside with redispatch, security restrained OPF, zonal based approach with sensitivity factors, and force of FACTS to administer transmission congestion minimizing the congestion cost is offered [12] [13].

Numerous methods are applied such as FACTS devices in congestion management, which location can be based on fixed or vibrant presentation of the system [14] [17]. The congestion administration is a general with exacting systematic modes of improving electricity transmit in which power systems scheduling and working can be considered [18]. For fixed congestion management [15] [16], excess sensitivity factor (power flow index) is applied for optimal location of series FACTS devices. Evolutionary algorithms (EAs) like evolutionary programming (EP), Genetic Algorithm (GA), Differential (DE) and Particle Swarm Optimization (PSO) are broadly used during previous two decades in the field of engineering optimization [18-20].

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During transmission congestion, collective technique is suggested for rearranging the generator components in the manuscript. The suggested method is the mixture of cuckoo search (CS) algorithm and artificial neural network (ANN). CS algorithm motivated by the necessitate brood parasitism of some cuckoo species by resting their eggs in the shells of other horde birds. It is idealized such breeding behavior, and hence can be used for different optimization problems. At this point, the CS algorithm is optimized the actual power transforms of the generator as transmission congestion is happened. A fake neural network is a mathematical replica which contains an interrelated set of artificial neurons, which to diminish the computational complexity of CS algorithm. According to the crammed power, ANN is applied to decide the actual power of generators. In section 3, the specified report of suggested technique and the problem formulation are offered. Ahead of that, in section 2, the current research efforts are assessed. In section 4, the results and discussion are explained and the section 5 winds up the manuscript.

2. RECENT RESEARCH WORK: A BRIEF REVIEW

Different research works are existing in literature that based on congestion supervision in deregulated electric power system. A few of them are assessed here.

Based on a transient stability criterion, a congestion management method has been brought in by Masoud Esmaili *et al.* [21]. With the understanding of accurate transient stability margin with regard to generations and demands, the suggested method so improves the congestion that the network could further keep hold of its transient security compared with previous methods. Reflecting on the likelihood of credible errors, the proposed transient constancy index was erected. Definitely, market parties take part by their security-effective bids rather than unrefined bids. Effects of testing the planned method beside with the previous ones on the New-England test system highly structured the competence of the proposed method from the opinion of offering an improved transient stability margin with a lesser security cost.

Using resource allocation technique, AC load flow-based decentralized replica for congestion administration in the onward markets has been proposed by Visalakshi, S *et al.* [22]. Distributed by independent system operator, each deal maximizes its yield under the limits of transmission line capacities in this replica. The voltage and reactive power impact of the system were moreover integrated in the replica. To work out decentralized congestion management problem for polygonal dealings, a covariance matrix adapted evolution strategy (CMAES) algorithm was exploited. The planned strategy was checked on IEEE 30 bus, IEEE 118 bus and realistic Indian usefulness 62 bus systems for three, six and two polygonal transactions, correspondingly, with even and non-smooth cost functions. Using CMAES algorithm, the results gained for decentralized model was compared with particle swarm optimization (PSO) algorithm and sequential quadratic programming (SQP) method.

Ch Venkaiah *et al.* [23] have offered a technique of fuzzy adaptive bacterial foraging (FABF) based congestion management (CM) for the first time by optimal rescheduling of dynamic powers of generators chosen based on the generator sensitivity to the crowded line. In the suggested method, generators were chosen based on their sensitivity to the crowded line to use the generators competently and optimal rescheduling of the dynamic powers of the participating generators was tried by FABF. The FABF algorithm is checked on IEEE 30-bus system and Practical Indian 75-bus system and the answers were compared with the Simple Bacterial Foraging (SBF) and Particle Swarm Optimization (PSO) algorithms for toughness and efficiency of congestion management. It was viewed from the answers that FABF was successfully minimizing the cost of generation in comparison with SBF and PSO for optimal rescheduling of generators to alleviate congestion in the broadcast line.

Using a mixture of demand response (DR) and stretchy alternating current transmission system (FACTS) tools, A.Yousefi *et al.* [24] have suggested for transmission lines congestion management in a reorganized market surroundings. A two-step market clearing system was prepared to attain this plan. In the initial stage, generation companies offer to the market for maximizing their return, and the ISO apparent the market based on social welfare maximization. In the second stage of the market-clearing system, network restraints together with those connected to congestion management are signified. The manuscript grows, by means of varied integer optimization method, a re-dispatch formulation for the second step in which demand answers and FACTS device controllers were optimally matched with conventional generators.

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In market-based power systems, a particle swarm optimization (PSO)-based algorithm has been offered by Hajforoosh, S. *et al.* [25] to execute congestion management by suitable appointment and sizing of one unified power flow controller (UPFC) tool. The algorithm employs quadratic smooth bends for generators' costs. To develop the precision of the model by integrating the impacts of load difference on the optimization problem, a distinctive load duration curve (LDC) was applied. To distribute the near-optimal GenCos, the suggested approach formulates use of the PSO algorithm with the optimal location and size of UPFC while the Newton Raphson solution diminishes the inequality of the power flow equations. To examine the bang of UPFC on the blocking stages of the dependability test system (RTS) 24-bus test system, replication results were utilized. Simulation effects by the suggested PSO algorithm were moreover compared with solutions gained by the conventional sequential quadratic programming (SQP) approach.

Using generation rescheduling with N-1 contingency in reorganized power system, Sujatha Balaraman *et al.* [26] have suggested a meek effort to address an intelligent method based on Cascade Back Propagation Neural network (CBPN) for finding of line overloads, forecast of overloading amount and improvement of overloads. The power communication blocking has turn out to be more increased and recurrent than the perpendicularly bundled system. Transmission line congestion begins the cascading outages which powers the system to crumple. To evade network crumple, precise forecast and improvement of line overloads were the appropriate counteractive achievements. The clear method for network Congestion Management (CM) was postponementing the power output of generators. The suggested CBPN contains three Artificial Neural Networks (ANNs) in tumble. The efficiency of the suggested approach is checked for different contingencies in the IEEE 30 Bus System.

To find out the number of generators involving in congestion administration, K. S. Pandya *et al.* [27] have offered dynamic and reactive power generator sensitivity features of the generators to the crowded lines. Next, to reduce the variations of rearranged values of dynamic power and reactive power of generators from scheduled values, a particle swarm optimization based algorithm has been proposed regarding the voltage stability improvement and voltage profile development criteria. As a result, by particle swarm optimization, rearrangement costs of dynamic power and reactive power were diminished. The efficiency and possibility of the suggested algorithm have been checked on IEEE 30-bus and New England 39-bus systems, and the attained results have been compared with earlier literature in terms of solution class.

The blocking is one of the multiobjective setbacks in deregulated power system which was shown from the assess of the current research work. This overcrowding is happened due to the causes of power flows across broadcast lines and transformers than the physical borders of those lines. For executing transmission congestion by rearranging the generation units, dissimilar sorts of congestion administration methods previously available. For this reason, the congestion administration problem is regarded as a non convex optimization problem with further number of equality and in equality restraints; it can never be directly worked out by mathematical techniques.

To have excellent features, Conventional optimization techniques undergo from the local optimality problem and a few of them generally need the function, such as continuity, differentiability etc., this limits the application of these traditional methods to a tiny variety of actual word problems. The local search algorithm is not proper for broad area search problem. The genetic algorithm is a population based global search algorithm but, it not proper for local search algorithm. To work out this problem a local and global search algorithm based congestion administration method is required. ANN and CS algorithm base collective congestion administration method is suggested n the paper. The setback formulation and the detailed report of the suggested technique are addressed in the subsequent section.

3. PROBLEM FORMULATION: AN OVERVIEW

Generally, transmission congestion management of power system incorporates with system constraints. The power balance condition and optimal power flow depends on the system constraints such as, real power of generators, reactive power of the generators, voltage limits and etc. In the paper, a combined congestion management technique is proposed for rescheduling the generators. The congestion management cost function, power balance condition, power flow limits of generators, voltage limits and generator sensitivity factor are considered in the proposed

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approach. The described function, condition, and factor are addressed in detail as follow,

Congestion management: In the manuscript, the actual power generation stage of the generator rescheduling from the chosen schedule is regarded as to decrease the blocking. The incremental and decremental generator price bidding costs are presented by each and all generating unit to the system operator. This price bidding is useful to calculate approximately the minimum cost necessary to take away blocking is called as congestion cost. The mathematical phrase of congestion management cost is explained as,

Minimize congestion management cost,

$$CM = \sum_{g=1}^{N_g} \left(C_g^i \Delta P_g^i + C_g^d \Delta P_g^d \right) \quad (1)$$

Where, C_g^i and C_g^d are the incremental and decremental cost coefficients of the generator. ΔP_g^i and ΔP_g^d are the changes in generator power from preferential schedule in positive or negative side generator.

Constraints of power balance: The power balance state of the system depends on the rule of equilibrium between total generation and total load of the system. The power balance state is characterized in terms of nonlinear power flow equations which illustrated as follow,

$$P_{G_x} = P_{D_x} + \sum_{y=1}^{n} |V_x||V_y||Y_{xy}| \cos(\theta_{xy} - \delta_x + \delta_y) \quad (2)$$

$$Q_{G_x} = Q_{D_x} + \sum_{y=1}^{n} |V_x||V_y||Y_{xy}| \sin(\theta_{xy} - \delta_x + \delta_y) \quad (3)$$

Where, P_{G_x} Q_{G_x}, P_{D_x} and Q_{D_x} are the real and reactive power injected at x^{th} bus and the corresponding load demands respectively. Y_{xy} and θ_{xy} are the admittance matrix and voltage angle between x^{th} and y^{th} buses. V_x, V_y, δ_x and δ_y are the magnitude and angle of bus x^{th} and y^{th} respectively. Then, the real power loss of the system is modeled as follow,

$$P_{loss} = z\sum_{z=1}^{N_L} G_z \left[|V_x|^2 + |V_y|^2 - 2|V_x||V_y| \cos(\delta_x - \delta_y) \right] \quad (4)$$

Where, G_z is the conductance of transmission line which connected between x^{th} and y^{th} buses respectively.

Generator power constraints: The production limits of the generating units are separated into upper and lower bound which reclines in between the real limits. The real, and reactive power are explained as following them,

$$P_{G_x}^{\min} \le P_{G_x} \le P_{G_x}^{\max} \quad (5)$$

$$Q_{G_x}^{\min} \le Q_{G_x} \le Q_{G_x}^{\max} \quad (6)$$

Where, $P_{G_x}^{\min}$ and $P_{G_x}^{\max}$ are the lower and upper bounds of real power of x^{th} generator unit. $Q_{G_x}^{\min}$ and $Q_{G_i}^{\max}$ are the lower and upper bounds of reactive power of x^{th} generator unit.

Voltage limits: After executing the load flow study, the voltage degrees of the each and every load buses should be authenticated between its bound. This voltage degree is having its own lower and upper bound and mathematically signified by follow,

$$V_x^{\min} \le V_x \le V_x^{\max} \quad (7)$$

Where, $V_x^{\min}$ and $V_x^{\max}$ are the voltage limits of x^{th} bus.

Generator sensitivity: The sensitivity of generator is varied by the limits of transmission line congestion. It is defined as the ratio of change of line real power and the change of generated power. The sensitivity of generated is denoted as S which is described as follow,

$$\text{Generator sensitivity } S_g = \frac{\Delta P_{xy}}{\left(\Delta P_g^i + \Delta P_g^d\right)} \quad (8)$$

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

Where, ΔP_{xy} is the change of line power, $S_g^{\min}$, $S_g^{\max}$ are the sensitivity limits of the generator, and $\Delta P_g = \Delta P_g^i + \Delta P_g^d$ is the change of generator power.

3.1. Proposed ANN based CS Algorithm

To work out the problem belongs to optimization, Cuckoo search is one of the metaheuristic algorithms that is used. In mixture with the Levy flight behavior of some birds and fruit flies in nature [28], this algorithm is motivated by the needed brood presentation of cuckoo species. To explain the cuckoo search in plainly, we have three idealized rules which are considered as: 1) Each cuckoo lays one egg at a time, and dump its

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egg in randomly chosen nest; 2) The best nests with high quality of eggs will carry over to the next generations; 3) The number of obtainable host nests is permanent, and the egg laid by a cuckoo is found out by the host bird with a possibility [29] [30]. The value or fitness of a solution can merely be comparative to the minus value of the objective function [31] in the case of minimization problems. Probing of solution depends on the lower and upper limits of the solution series in CS algorithm. According to the crowded power by synthetic neural network (ANN), superlative reschedule importances are made as a dataset from the generator limits. ANN is a synthetic intelligence (AI) method which applied for optimizing precise generation limits as blocking happened. The neural network contains two stages: training stage and testing stage and it contains three layers: input layer, hidden layer and output layer. In the manuscript, feed forward neural network (FFNN) with back propagation teaching algorithm is applied. The flow chart for suggested approach is explained in Fig.1.

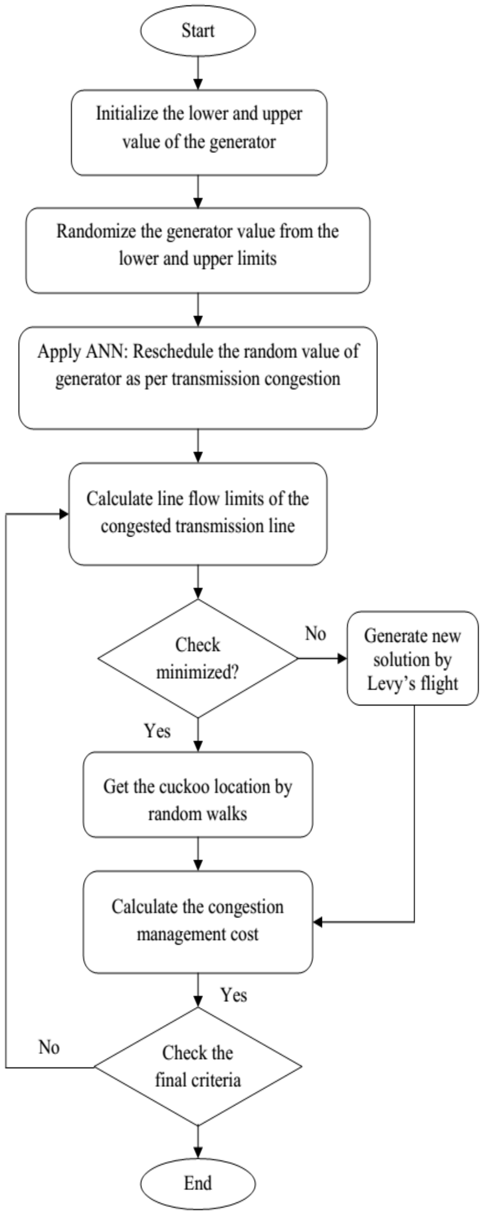

Fig. 1: Flow chart of CS for proposed approach.

Steps of cuckoo search:

(i) Initialization

In the first step, the generator values are initialized from the allowable range i.e. the upper and lower limits. From the initialized limits, each generator values are randomized and the values are expressed as follow,

$$G_i = [g_0^{(i)}\ g_1^{(i)} \ldots\ldots g_{N_L-1}^{(i)}] \qquad (10)$$

Where, N_L is the length of the randomized values, and G_i is the random value of i^{th} generator

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which includes by their limits. The equation (10) contains the reschedule value of all the generators. When congestion is to be occurred, the optimal generator values are selected from the randomized values.

(ii) Apply ANN

In training phase of ANN, generator limits are trained by the congested line power. A pre-examined dataset is obtained from and it is used as the training dataset X for neural network. The dataset X is consisted of input as transmission line congested power and the system output (target) is the reschedule power of the generators. The dataset X can be represented as,

$$X = \begin{bmatrix} c_0^{(i)} \\ c_1^{(i)} \\ \vdots \\ c_{N_L-1}^{(i)} \end{bmatrix} \begin{bmatrix} g_0^{(i)} \\ g_1^{(i)} \\ \vdots \\ g_{N_L-1}^{(i)} \end{bmatrix} \quad (11)$$

where, $c_0^{(i)}$, $c_1^{(i)}$,….., $c_{N_L-1}^{(i)}$ transmission line over loaded values and $g_0^{(i)}$, $g_1^{(i)}$,….., $g_{N_L-1}^{(i)}$ are the reschedule value of all the generator units. The feed forward network structure is described in Fig.2 which illustrated as follow,

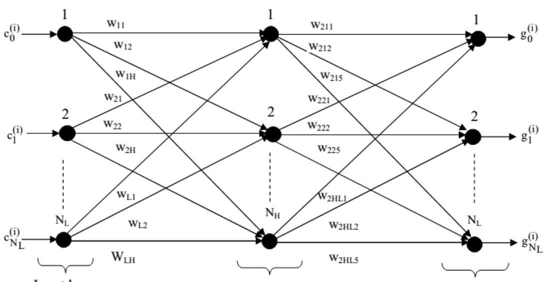

Fig. 2: Structure Of Neural Network With Proposed Approach Data.

Back propagation training algorithm:

Step 1: Assign arbitrary weights generated in the interval $[w_{\min}, w_{\max}]$ to the hidden layer neurons and the output layer neurons. Assign unity value weights to each neuron of the input layer.

Step 2: Determine the BP error by giving the training dataset X as input to the classifier as follows,

$$BP_e = g_T - g_{out} \quad (12)$$

In Eq. (2), g_T are the target output and the network output g_{out} can be calculated as $g_{out} = [g_0 \; g_1 \; g_2 \cdots g_{N_T-1}]$. The elements of g_{out} can be determined from every output neuron of the network as follows,

$$g_{out} = \sum_{i=1}^{N_H} w_{ij} y_i \quad (13)$$

where,

$$y_i = \frac{w_{1i}}{1+\exp(-c_1^{(i)})} + \frac{w_{2i}}{1+\exp(-c_2^{(i)})} + ... + \frac{w_{ni}}{1+\exp(-c_{N_L}^{(i)})}; \quad 1 \le i \le N_L \quad (14)$$

In Eq. (13) N_H is the number of hidden neurons, g_{out} is the output from j^{th} output neuron and w_{ij} is the weight of the $i-j$ link of the network. In Eq. (14), y_i is the output of i^{th} hidden neuron.

Step 3: Determine the change in weights based on the obtained BP error as follows

$$\Delta w = \gamma . g_{out} . BP_e \quad (15)$$

In Eq. (15), γ is the learning rate, usually it ranges from 0.2 to 0.5.

Step 4: Determine the new weights as follows

$$w_{new} = w_{old} + \Delta w \quad (16)$$

Step 5: Until BP error gets reduced to a least value, repeat the process from step 2. Essentially, the condition to be satisfied is $BP_e < 0.1$.

The network gets well-trained when the process is completed. In testing phase, the congested real power applied to network and the exact reschedule generator powers are provided by the trained network. The network output is applied to the evaluation stage.

(iii) Evaluation

During evaluation, the current best nest is calculated from the initialized values. The initialized values are relevant to the objective function, then go to step (v). Otherwise construct the loop by cuckoo random walk which describe in step (iv).

(iv) Loop construction

In the step, generator values are rescheduled for removing the congestion of transmission line. Generator units reschedule power values depends on the cost function of the congestion management. Then, check the system condition balanced or not. If the condition is satisfied, cuckoo turns the location by randomly and evaluates the fitness function. Otherwise, generate a new egg in CS, a Levy flight is performed using the coordinates

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of an egg selected randomly which can represented as follow,

$$x_i^{t+1} = x_i^t + \alpha \Theta Lev'y(\lambda) \quad (17)$$

Where, Θ denotes the entry wise multiplication, α is the step size and $Lev'y(\lambda)$ is the levy distribution.

(v) Fitness evaluation

The fitness function of the solution is evaluated and which represented as follow,

$$fitnessfunction = \min(CMC) \quad (18)$$

Where, CMC is the congestion management cost.

(vi) Solution construction

At the end of maximum iteration, check the final solution and whether the solution is minimized the objective function; then, stop the process otherwise extends the solution until to the satisfied condition.

Pseudo code for proposed ANN based cuckoo search approach.

```
Initialize the population of 'n' host nest H_n, n = 1,2,3....,k
Apply ANN and predict H_n^predict
For all H_n^predict do
        Calculate fitness function X_n = f(H_n^predict),
        f(H_n^predict) = min(CMC)
End for
While (Number of iterations<Maximum number of iteration) or (stopping criteria satisfied) do
        Cuckoo egg X_l generate by taking a Levy flight from random nest,
        H_l = f(H_l)
        Choose a random nest 'i'
        If (X_l > X_n) then, X_n <- X_l, f(H_n^predict) <- H_l
End if
        Discard a portion of the worst nests,
        New nests build at new positions via Levy flight to replace nests lost,
        Approximate fitness functions of new nests and grade all solutions.
End while
```

4. RESULTS AND DISCUSSION

The proposed combined congestion management technique was implemented in MATLAB working platform. Then, the congestion managing performance of the proposed technique was tested with IEEE 30 bus bench mark system. The tested system consists of 6 generator buses and 24 load buses. The network topology and the test data for the IEEE 30-bus system can be found in http://www.ee.washington.edu/research/pstca. In the proposed case, the transmission congestion is created by randomly loading the transmission line to crosses its thermal limits. According to the overload of transmission line, rescheduling is performed by the proposed combined technique. Here, the CS algorithm is used to initialize the real power variation of the system. Then, ANN is used to predict the preferred reschedule generator value corresponding to the congestion of transmission line. The bidding cost and generation limits of testing system are tabulated in Table I. The implementation parameters of cuckoo search and ANN are illustrated as follow,

***Table 1.** Bidding Cost And Generation Limits*

Number of nest for each generator: 50
Number of iteration: 150
Number hidden layers of ANN: 30

Generator number	Generator limits		Bidding cost	
	P_{min}	P_{max}	(C_g^i)	(C_g^d)
G_1	50	200	45	40
G_2	20	80	40	28
G_5	15	50	45	32
G_8	10	35	40	38
G_{11}	10	30	42	40
G_{13}	12	40	48	25

For evaluating the performance of the proposed technique, the congestion occurred line is considered in between bus-10 and bus-17. This congestion is created by increasing the demand of load bus. In congested line, real power flow after congestion is 5.928 MW. The result of congestion, power loss of the system is increased to 13.063 MW. After applying the congestion management technique, the congestion of the line is reduced as 5.48 MW and the power loss is reduced as 9.3396 MW. For the reason of optimal rescheduling of the

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real power generation of the generators, the congestion has to be relieved. Then, the sensitivity of the generator is calculated after rescheduling real power by using the sensitivity equation. According to the sensitivity of generator, the generators which are to participate in congestion management can be analyzed. In this test system, it is observed that all the generators show strong influence on the congested line. This is perhaps the system is very small and generally very tightly connected electrically. The generator sensitivity chart of the proposed system after solving the transmission line congestion between bus 10 and 17 is illustrated in Fig.3.

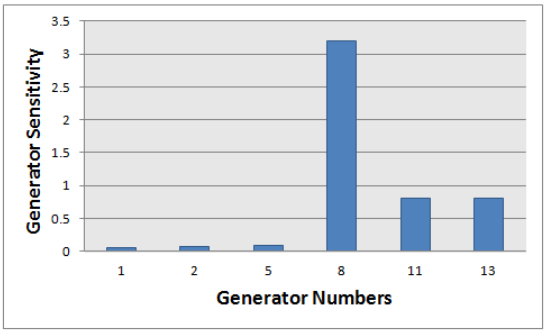

Fig. 3: Generator Sensitivity After Solving Congestion Of Line Between Bus 10 And 17.

The real power follow of the line (bus 10 and bus 17) of the proposed method is analyzed before managing congestion and after managing congestion. The analyzed values are compared with CS algorithm and PSO algorithm [32] which gives in Table II. The comparison chart of the congested line before and after managing congestion is illustrated in Fig.4. Then, the real power flow of the generator before and after managing congestion is analyzed. The real power generation by the 6 contributing generators before the congestion management and after the congestion management utilized is give in Table III. The rescheduling of active power of the contributing generators by ANN-CS, CS and PSO are pictorially represented in Fig.5 and Fig.6 respectively for comparison with active power generation before and after congestion management.

Table 2. Real Power Flow Of Congested Line Before And After Congestion Management

Real power flow		Real power (MW) before congestion management	Real power (MW) after congestion management		
From bus	To bus		ANN-CS	CS	PSO [32]
10	17	5.928	5.48	5.828	5.9

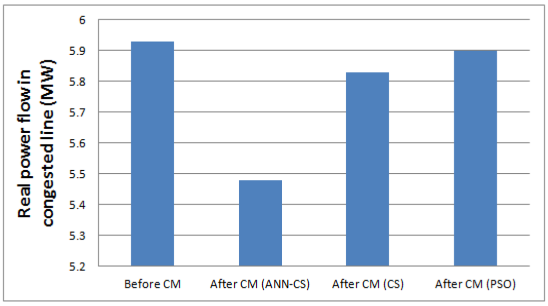

Fig. 4: Real Power Flow Of The Congested Line Between Bus 10 And 17.

The reschedule generator limits are described after removing the congestion of the system while congestion occurred in between buses 10 and 17. The congestion management cost of proposed method for rescheduling the generator units described in Table IV. The comparison chart of congestion relieving cost of ANN-CS, CS and PSO is illustrated in Fig.7.

For evaluating the performance of proposed method, the different congestion levels are used. So that, different buses are used for generating the transmission congestion which is illustrated in Table V. Then, the power loss of the system is evaluated before and after congestion management. Also, the congestion management cost of the proposed method is determined. The comparison chart of power loss is presented in Fig.8. The congestion management solution converging by proposed method and CS algorithm are compared. The comparison of convergence performance is illustrated in Fig.9.

Table 3. Real Power Generation Before And After Congestion Management

Generator number	Real power (MW) before congestion management (BCM)			Real power (MW) after congestion management (BCM)		
	ANN-CS	CS	PSO	ANN-CS	CS	PSO [32]
G_1	171	185	185.046387	71.5788	115.293	184.240386
G_2	67	61	46.795654	70.9483	22.73134	46.632538
G_5	40	40	19.102783	36.7894	21.96836	20.564745
G_8	30	30	10	12.5648	23.6881	10
G_{11}	28	27	10	29.7071	11.33756	10
G_{13}	37	36	12	27.198	20.57916	12

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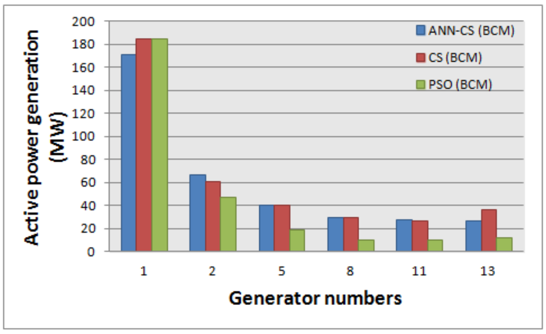

Fig. 5: Real Power Before Congestion Management.

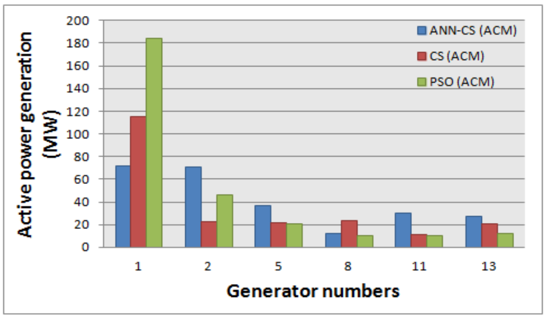

Fig. 6: Real Power After Congestion Management.

Table 4. *Comparison Of Congestion Management Cost*

CM cost (Rs./MWh)	ANN-CS	CS	PSO [32]
Best	149.49	150.905	160.23
Worst	150.001	151.375	161.61
Mean	149.7455	151.14	161.49

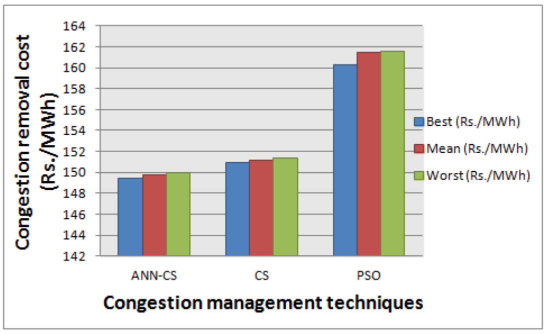

Fig. 7: Comparison Of Congestion Removal Cost.

Table 5. *Congestion Management Cost And Power Loss Of Proposed Technique*

Congested line		Congestion management cost (Rs./MWh)	Real power loss (MW)	
From bus	To bus		BCM	ACM
3	4	148.983	14.7442	8.5384
9	10	149.378	12.939	8.0174
10	17	149.190	13.063	9.3396
12	14	149.462	13.8218	7.8934
17	18	149.413	13.089	10.3255

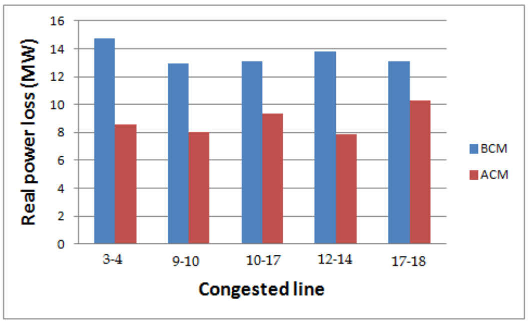

Fig. 8: Power Loss Of Proposed Method Before And After Congestion Management.

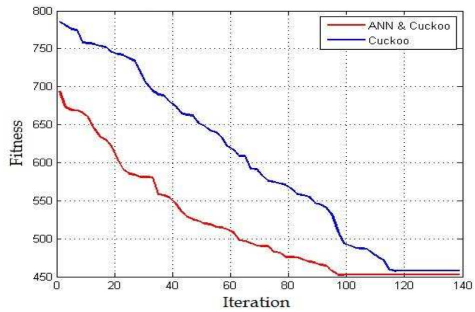

Fig. 9: Convergent Of Proposed Congestion Management Technique.

From the comparative analysis, the robustness of the proposed method is exposed for managing the transmission congestion of IEEE 30 bus system. In Table IV shows that, the best value, worst value and mean value after the congestion management for optimal rescheduling of the real powers of the contributing 6 generators. Also, the comparison chart representation of cost of CM employing ANN-CS, CS and PSO is revealed in Fig.7. From Fig.7 it is observed that the proposed technique gives minimum CM cost for rescheduling of real power of contributing generators to remove the transmission congestion. In additionally, the time taken by the proposed method for reaching the solution is lesser than that the CS algorithm and PSO [32] which revealed by the convergence graph. Hence, the computational burden of the CS algorithm is reduced by the inclusion of ANN for solving power transmission congestion.

5. CONCLUSION

In the paper, ANN and CS algorithm were combined for removing the transmission congestion of the power system. The congestion management performance of the proposed technique was tested with IEEE 30 bus system. The proposed method was compared with CS algorithm and PSO algorithm. From the comparison, proposed method

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reschedules the real power of generation effectively. So the congestion management cost of the proposed method reduced as compared to CS and PSO algorithm. Then, the power loss of proposed method is determined at different congestion level. The analysis shows that, the proposed method remove the congestion management effectively to compare with CS and PSO algorithm. Since, the proposed combine technique (ANN-CS) is efficiently removing transmission congestion by reschedule the generator.

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