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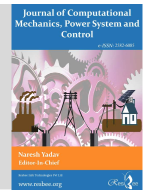

Hybrid Dragonfly and Particle Swarm Optimization Algorithm for Congestion Management

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Abstract: The transmission line undergoes large disadvantages of insecurity as well as discrete power flows regarding the rescheduling cost. In the Transmission line, an optimal solution for this discrete as well as secure power flow is attained from the Real Power Balance Constraint (RBCM) method. To produce a limited solution a large number of optimization approaches is used for congestion management. In this work, a highly powerful method as the Hybrid Dragonfly and PSO algorithm named (DA-PSO) with the main contribution to resolve the cost of congestion with minimizing rescheduled cost. Furthermore, to identify the improvement in the developed approach performance regarding congestion an analysis is performed among the developed and existing techniques in order to fulfill the analysis. The performance analysis examination outcome exhibit that the developed model is highly superior to the conventional models regarding the reduced rescheduling cost.

Keywords: Congestion Management, Optimization Algorithm, Power Flow, Rescheduling Cost, Transmission Line.

Nomenclature

Abbreviations	Descriptions
ACO	Ant Colony Optimization
CAISO	California ISO
GA	Genetic Algorithm
RUL	Ramp up Limits
SA	Simulated Annealing
DESS	Distributed Energy Storage System
DLFU	Disparity Line Utilization Factor
APO	Active Power Output
PSO	Particle Swarm Optimization
FACTSs	Flexible AC transmission systems
GCC	Generation Capacity Constraint
OPF	Optimal Power Flow
PV	Photo voltaic
DG	Distributed Generator
SL	Stability Limits
GSA	Gravitational Search Algorithm
ITVAC	Improved Time-Varying Acceleration Coefficients
RPBC	Real Power Balance Constraint
ESS	Energy Storage System
TCSCs	Thyristor Controlled Series Compensators
DE	Differential Evolution

1. Introduction

The operation manner, ownership, structure, and utilities management are change by the deregulated electric power industries. In deregulated as well as competitive markets, the transmission congestion problem is highly well-known which requires a suitable management scheme [1]. For the electric uses, it is very important to operate in the new competitive electric market so that it creates superior

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consumption of the conventional transmission facilities in combination to maintain the stability, security as well as supplied power reliability. For the conventional transmission lines, transmission facilities, lie to obtain congested or overloaded in the procedure of superior use. In the transmission lines, raised congestion might tend to an incident in the network. An uncontrolled contingencies series is represented as the important cause of blackouts. Therefore, to appropriately use the transmission lines as well as at a similar time the stability, security well as reliability is maintained of the transmission system, the FACTS devices employ turns out to be predictable. The number of FACTS devices, which can be exploited in the economic constraints put a restriction. Therefore, the optimal positioning and the FACTS devices tuning in the power system are obligatory [2].

Because of deregulation, the prologue of competition may cause the cost-based electricity to transfer into a price-based market product [3]. The net electricity cost is reduced by the raised competition and the market forces are driven by electricity prices. In new liberalized market competition, may cause self-determining endangering usefulness to sell all their produced power to the customers [12]. Therefore they attempt to contain all their produced power on the transmission line that might occur transmission line infringement limits namely voltage limit, thermal limit, and stability limit so on therefore occurs the congestion in a transmission line. The congestion in transmission line might tend to overload lines tripping, instability of power system so on, also apparently raise the electricity cost as it happens the power system to diverge from its optimal operation. Therefore, the congestion requires to ease rapidly[4].

To safeguard the system from serious circumstances, congestion management is exploited [9]. It is given maximum precedence by CAISO and FERC. Moreover, for congestion management, several techniques were exploited namely DE, OPF, and PSO [10]. In an electrical network, FACTS positioning significantly improves the power transfer ability of lines and networks. The FACTS devices are considered as the solid stated converters that control several electrical parameters in the transmission system as well as improve the stability of the power system. Numerous approaches were proposed until now to conflict congestion namely transmission line switching, generation rescheduling [11].

To optimize a non-linear function, numerous existing optimization approaches namely the interior point approach, Newton's approach, and gradient approach so on are present in state-of-art. As aforesaid existing techniques are iterative in nature and their search direction is ascertained from function derivative, hence it turns out to be essential to state the objective model in the type of continuous differential function. To override this issue, in the current day's meta-heuristics techniques namely evolutionary approach, GA, tabu search, ACO, SA, PSO so on are introduced. As PSO is a computational intelligence-based optimization approach that is not highly pretentious by optimization issue and size nonlinearity as well as it can converge to the optimal solution in numerous issues whereas largely analytical techniques fail to converge, thus it can be powerfully used for various optimization issues in power systems.

The major contribution of this research is to propose a new CM model with the aspiration of de-limiting the power system using Advanced Soft Computing Models. The main idea behind the generation rescheduling is used even if there subsist a count of congestion Management techniques. Moreover, it is attained using an optimization approach called Hybrid DA-PSO to resolve the objective function.

2. Literature Review

In 2009, Hadi Besharat and Seyed Abbas Taher [1], worked on a deregulated electricity market. The enduring restructuring of the power system needs an opening of unemployed potentials of the transmission system. It was because of environmental, main concern, and cost issues that were the most important obstacles for expansion of power transmission network. To minimize the flows in heavily loaded lines, FACTSs devices were an option, ensuing in a minimum system loss, maximized loadability, minimized production cost, enhanced network stability, as well as a satisfied contractual obligation by controlling the power flows in the network. Here, an approach to establish the optimal TCSCs position was recommended based on minimization of total system VAR power losses and performance index of real power. In 2017, Akanksha Mishra and Venkata Nagesh Kumar [2], worked on a DLFU for optimal positioning as well as GSA-based optimal tuning of IPFC for the congestion control in transmission lines. Regarding the relative line congestion, the DLFU ranks the transmission lines. In the majority congested line, the IPFC was positioned as well as in the minimum congested line was linked to a similar bus. In order to tune the IPFC parameters, a multi-objective function was chosen. In 2020, Divya Asija et al [3], worked on the Solar PV beside with ESS was exploited as DESS. During off-load period to accumulate excess energy; ESS beside DG was exploited that was used at peak load thus improving the complete system effectiveness. In 2016, Md Sarwar and Anwar Shahzad Siddiqui [4], worked on a technique to deal with congestion in the deregulated environment by exploiting the PSO-ITVAC. On the basis of the generator sensitivities magnitude, the congestion was lessened by selecting the optimally rescheduling the generator's active power output. By exploiting the PSO-ITVAC the rescheduling cost was reduced. In 2012, Nima Amjady and Mahmood Hakimi [5], worked on a novel congestion management model taking into consideration of power system dynamic voltage stability boundary. Therefore this reason, accurate dynamic modeling of power system equipment, such as loads as well as generators, was integrated into the developed CM model. The developed technique mitigates congestion with a minor cost of CM and more dynamic voltage stability margin, ensuing in a highly robust power system, evaluated to the preceding CM approaches.

3. Congestion Management Formulation in Deregulated Power System

3.1 Congestion Cost

In the electrical environment, congestion can be minimized using the generator's APO rescheduling. The process of rescheduling can be attained, by falling or expanding in the APO. This reduction or de-accelerating or in the cost of APO requirements as well as this cost is present regarding the price bids that are being submitted using GENCOs. For scheduling cost incurred, is indicates as the cost of congestion as well as the mathematical formulation of congestion cost is referred to as in eq. (1) in that the cumulative cost needed to modify APO is indicated regarding (\$/n) is stated as C_{total} and $C_j : j = 1,2,\ldots,N_g$. To expand the price bids and power is referred to as D_j indicated regarding \$/MWn by j^{th} GENCO. $\Delta P_G^+(j)$ and $\Delta P_G^-(j)$ represented as AP expanded and generator decrement (MW). $\Delta P_G^+(j)$ as well as $\Delta P_G^-(j)$ states the change in AP. In AP the change is stated as the "absolute difference amid price bids submitted at the present hour (n) from the preceding hour (n-1)" and the mathematical formulation of change in AP is stated as ΔP_G, is exhibited in Eq. (2). Here, the AP produced at the preceding hour and the current hour are shown as $P_G(n)$ and, $P_G(n-1)$ correspondingly.

$$C_{total} = \sum_{j \in N_g} (C_j \Delta P_G^+(j) + D_j \Delta P_G^-(j))\$/n \tag{1}$$

$$\Delta P_G = | P_G(n-1) - P_G(n) | \tag{2}$$

3.2 Constraints

To overrule the issue of congestion, the rescheduling scheme is used with low minimum rescheduling cost. The constraints namely GCC, RPBC, SL, and RUL are exploited at the time of the rescheduling operation of the power generators. Hence, it is necessary to model a minimum rescheduling cost based on the Constrained Minimization Function (CMF). For G^{th} generation unit, the change in the AP generated using MW is signified as ΔP_G whereas, $\Delta P_G : 0 \le j \le N_g$ (MW) for a cost of $f(\Delta P_G)$ regarding represented concerning \$. The minimization function is stated in eq. (3).

$$S^* = \underset{\Delta P_G \forall G}{\arg} \min \sum_{j=1}^{N_g} f(\Delta P_G(j)) \tag{3}$$

Furthermore, Eq. (I3) experiences the following constraints

a) GCC:

The AP quantity which is produced regarding MW is simplified as P_G is stated in eq. (4). P_G^{max} referred to as the maximum quantity produced in MW, whereas P_G^{min} represents the least quantity generated in MW. The P_G value is estimated on the basis of eq. (5), and the power quantity which is being produced is signified as ΩP_G.

$$P_G^{min} \le P_G \le P_G^{max} \tag{4}$$

$$P_G = \Omega P_G + \Delta P_G \tag{5}$$

b) RPBC

In eq. (6), P_{TL} indicates the transmission loss in MW and P_{PD} indicates the power demand. For transmission loss P_{TL} mathematical formulation is stated in eq. (7), where the loss coefficients are C_{ij}, C_{0j}, C_{00}.

$$\sum_{j=1}^{N_g} P_G - (P_{PD} + P_{TL}) = 0 \tag{6}$$

$$P_{TL} = \sum_{i=1}^{N_g} \sum_{j=1}^{N_g} (P_i C_{ij} P_G) + \sum_{j=1}^{N_g} (C_{0j} P_G) + C_{00} \tag{7}$$

c) SL

The sequential stability limits are exploited to explain and to assure the congestion alleviation stated. From the generator, the voltage stability is explained regarding the angle limits $(\partial_G^{\min}, \partial_G^{\max})$ as well as voltage limits $(V_G^{\min}, V_G^{\max})$. In MV and MPFL the power flow is signified as P_G^2, Q_G^2 and $S_G^{\max}$, correspondingly.

$$V_G^{\min} \le V_G \le V_G^{\max} \tag{8}$$

$$\partial_G^{\min} \le \partial_G \le \partial_G^{\max} \tag{9}$$

$$P_G^2 + Q_G^2 \le (S_G^{\max})^2 \tag{10}$$

d) RUL

RUL is represented as "up as well as down quantity limits of cost of rescheduling". The ramp limits are explained to create the rescheduling costs to turn out to be equal up and down.

$$\Delta P_G^{\min} \le \Delta P_G \le \Delta P_G^{\max} \tag{11}$$

In the least quantity generated the change in MW is $\Delta P_G^{\min}$ and $\Delta P_G^{\max}$ represents the change in the utmost quantity produced in MW. From Eq. (3), to convene the aforesaid constraints the optimal rescheduling scheme S^* is derived.

e) Objective Function

The cost of $f(\Delta P_g)$ represents the summation total of the cumulative cost acquired for rescheduling as well as violation level on the voltage of equivalent TL, for j^{th} generation unit. To describe RS, eq. (12) shows the cost function. The penalty cost which is used on violating the constraints is stated as $P_{constraints}$ and $P_{profile}$ represents the penalty cost forced on voltage profile. On the basis of eq. (13), the $C_{profile}$ value can be attained.

$$f(\Delta P_g) = C_{total} + P_{profile} C_{profile} + P_{constraints} C_{constraints} \tag{12}$$

$$C_{profile} = \left| \min\left(V_g - V_g^{\min}, 0\right) \right| + \left| \min\left(V_g^{\max} - V_g, 0\right) \right| \tag{13}$$

4. Proposed Hybrid DA-PSO Algorithm for Congestion Management

4.1 Conventional Dragonfly Algorithm

DA is enthused by the unique as well as better dragonflies' swarming behavior [6]. The migration, as well as hunting, is the behavior of the dragonfly swarms. Let us state dragonflies population size is N. The location of i^{th} dragonfly is stated in Eq. (14)

$$X_i = \left(x_i^1, x_i^d, \ldots\ldots, x_i^N\right) \tag{14}$$

Whereas $i = 1, 2, 3, \ldots, N$, N states count of search agents, x_i^d states location of the i^{th} dragonfly in d^{th} search space dimension.

On basis of the initial location values, the fitness function is estimated that is arbitrarily produced amid the upper and lower bounds of variables. s indicates the weight for separation, c indicates cohesion(c), a indicates alignment, f indicates food, and e indicates enemy factors for each dragonflywhich is initialized arbitrarily. In order to update the velocity, as well as location of dragonflies factors, are computed based on eq. (15) to (17).

$$S_i = -\sum_{j=1}^{N} X - X_i \tag{15}$$

$$A_i = \frac{\sum_{j=1}^{N} V_i}{N} \tag{16}$$

$$C_i = \frac{\sum_{j=1}^{N} X_i}{N} - X \tag{17}$$

whereas V_i and X_i states velocity and position of the i^{th} individual. N indicates a number of neighboring individuals and V_i indicates the current individual location. F_i indicates the Attraction towards a food source, E_i indicates the distraction from enemies, and its calculation is stated in eq. (18) and (19).

$$F_i = X^+ - X \tag{18}$$

$$E_i = X^- + X \tag{19}$$

Whereas, X signifies current individual position, X^- signifies enemy source as well as X^+ signifies the food source.

The neighborhood distance is computed using the Euclidean distance amid all the dragonflies as well as choosing N of them. r_{ij} indicates distance, which is computed using Eq. (20).

$$r_{ij} = \sqrt{\sum_{k=1}^{d} \left(x_{i,k} - x_{j,k}\right)^2} \tag{20}$$

On the basis of Eq. (21) analogous to velocity formulation of PSO as well as dragonfly location will be updated based on Eq. (22) that is analogous to the location formulation of PSO.

$$\Delta X_{t+1} = \left(sS_i + aA_i + cC_i + fF_i + eE_i\right) + w\Delta X_t \tag{21}$$

$$X_{t+1} = X_t + \Delta X_{t+1} \tag{22}$$

In the neighborhood, if there is no dragonfly radius dragonfly location will be updated exploiting Levy Flight [8] equation which is stated in Eq. (23). This enhances the arbitrariness, as well as global search capability chaotic behavior of dragonflies.

$$X_{t+1} = X_t + \mathrm{levy}(d) X_t \tag{23}$$

The fitness function is subsequently calculated on the basis of the updated velocities as well as location.

4.2 Conventional Particle Swarm Optimization Algorithm

PSO is a swarm intelligence optimization approach based on swarms social behavior [7]. Let N be dimensional search space. Consider velocity as well as the position of i^{th} particle in k^{th} iteration be X_k^i and velocity V_{k+1}^i correspondingly. The location and velocity of a particle in $(k + 1)$ iteration are updated as per Eq. (24) and (25) correspondingly.

$$V_{k+1}^i = wV_{k+1}^i + C_1 r_1\left(P_k^i - X_k^i\right) + C_2 r_2\left(P_k^g - X_k^i\right) \tag{24}$$

$$X_{k+1}^i = X_k^i + V_{k+1}^i \tag{25}$$

whereas C_1 indicates cognitive parameters and C_2 indicates social parameters, w indicates the inertial weight P_k^i and P_k^g represents the pbest of the ith particle.

4.3 Proposed Hybrid DA-PSO

An appropriate balance amid exploitation as well as exploration of search space is essential to attain a global optimal solution for any optimization approach. The exploitation or else called intensification engages search in a local region based on the present optimal solution and exploration or else called diversification engages global search in search space. In excess of exploitation and exploration destructively affect the approach performance by rising the convergence time as well as raising the probability to fall into local optima.

The traditional DA operates on an arbitrarily produced initial population of search agents as well as by exploiting Levy flight dragon flies explore the search space.

This arbitrary initialization as well as levy flight search procedure raises solution diversity and makes stronger the exploration ability of approach. Furthermore, DA possess merely some parameters to regulate as well as adaptive tuning of these swarming factors aids in balancing global and local search abilities.

Nevertheless,DA is short of an internal memory that can keep track of before attained possible solutions. At the time of the procedure, DA evades all the fitness values more than global optimal and by no means stays path on probable set of solutions that can converge to global optima. This weakens the exploitation ability of the DA attention to converge gradually and now and then idle at local optima. In order to evade this, a new hybrid approach on the basis of the PSO and DA is developed.

Here, 2 features are augmented to the existing DA approach to manage its performance, such as a) an internal memory to stay track of probable solutions that have a possible to converge to global optima b) hybrid with PSO in iteration level that runs on this set of stored solutions.

The velocity as well as position formulation of PSO is enhanced as

$$V_{k+1}^{i} = wV_{k+1}^{i} + C_1 r_1 \left(DA - Pbest_k^{i} - X_k^{i}\right) + C_2 r_2 \left(DA - gbest_k^{g} - X_k^{i}\right) \tag{26}$$

$$X_{k+1}^{i} = X_k^{i} + V_{k+1}^{i} \tag{27}$$

5. Simulation Setup

In this section, the experimental evaluation of the proposed technique was demonstrated. Here, IEEE 14 and 30 bus system was utilized as the benchmark test bus system to perform the experimentation analysis. Moreover, within the system, the TLs, CBs, and loads as well as generators were exploited. In IEEE 14 bus system, 3 GENCOS were used and in IEEE 14 bus system, 6 GENCOS were exploited in the IEEE 30 bus system. Moreover, the performance evaluation was performed on the basis of the cost of congestion, cost of compensation as well as final cost for both the developed and conventional models. Here, the proposed method was compared with the conventional models such as Artifical Bee Colony (ABC), Genetic Algorithm (GA) and Firefly (FF).

Fig 1 demonstrates the analysis of adopted as well as traditional techniques regarding congestion cost for both the IEEE 14 and IEEE 30 bus system. The analysis of the proposed and conventional models regarding the compensation cost for both the IEEE 14 as well as the 30 bus system is illustrated in Fig 2. Fig 3 shows an analysis of adopted as well as traditional techniques regarding the final cost for both the IEEE 14 as well as 30 bus system.

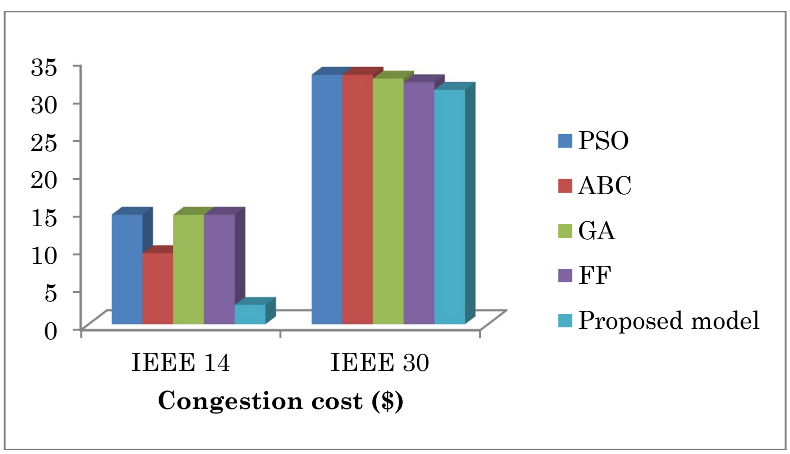

Fig. 1 *Performance analysis of the adopted as well as traditional approaches concerning congestion cost*

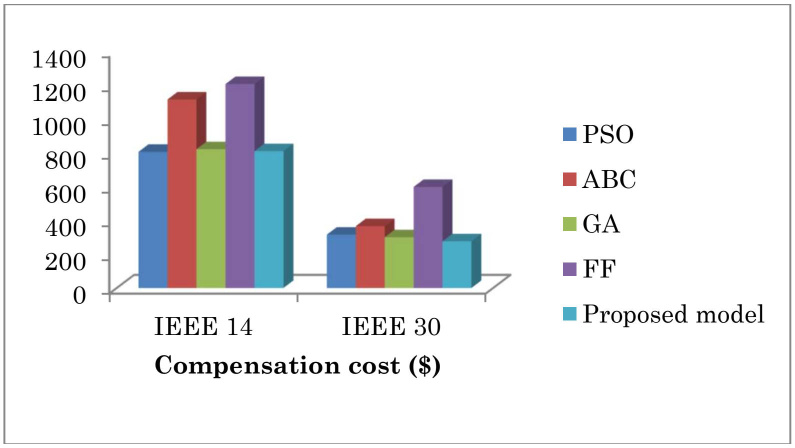

Fig. 2 *Performance analysis of adopted as well as traditional approaches concerning compensation cost*

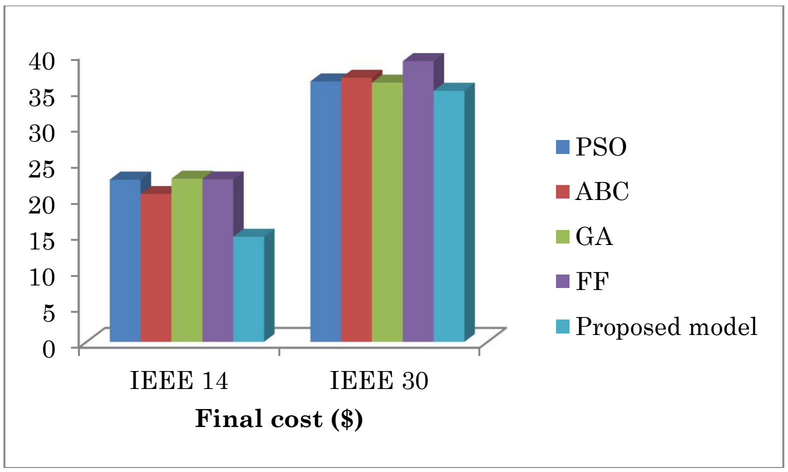

Fig. 3 *Performance analysis of the adopted as well as traditional approaches concerning the final cost*

Table 1 *Statistical analysis of the developed and traditional techniques for IEEE 14 Bus System*

Techniques	Best	Mean	Std	Worst	Median
PSO	21.641	21.666	1.11872	21.687	21.66
ABC	14.627	21.972	3.647	22.686	22.661
GA	21.644	21.372	1.1184	22.616	21.664
FF	22.684	22.697	1.11672	22.726	22.691
Proposed model	14.614	18.166	3.2412	21.648	21.621

Table 2 *Statistical analysis of the proposed and conventional models for IEEE 30 Bus System*

Techniques	Worst	Median	Std	Best	Mean
PSO	27.99	27.156	0.26267	27.044	27.222
ABC	27.901	27.759	0.10652	27.759	27.707
GA	27.002	25.659	0.07222	25.659	25.697
FF	26.976	26.767	0.17102	26.552	26.769
Proposed model	25.66	25.659	0.00927	25.659	25.672

The statistical analysis is performed in the obtained results to evaluate the conventional techniques for IEEE 14 and IEEE 30 bus system and it is summarized in Table 1 and 2.

6. Conclusion

The rescheduling of generation was utilized in this paper with the main objective of presenting the security to the power system and continual power supply with short of congestion in the TL. The generator was considered as one of the Congestion Management techniques as well it possesses confronts of reducing the cost of rescheduling. Therefore, the cost of rescheduling was reduced using an optimized approach in this work, as well as a performance-based evaluation was performed amid the proposed as well as conventional techniques. Here, the performance analysis was performed regarding the congestion and cost. Therefore, the overall analysis states that the performance of the developed technique was superior to the conventional methods regarding the reduced cost of congestion as well as compensation cost.

Compliance with Ethical Standards

Conflicts of interest: Authors declared that they have no conflict of interest.

Human participants: The conducted research follows the ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

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