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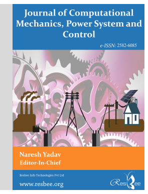

Design and Optimization of CEED using Hybrid Genetic Algorithm and Tabu Search Algorithm

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Abstract: The optimal system operation examines the operation economy, system security as well as emission from the plants to improve the efficiency of the power system. The Combined Economic Emission Dispatch (CEED) is taken as consideration as the approach to schedule the power generating units in their limits collectively with minimizing the emission values as well as fuel cost. In power system engineering, the complexity associated with the CEED involves a very important factor regarding the minimization of economic as well as emission cost. The main aim of this work is to present a novel approach called as Hybrid Genetic Algorithm (GA) and Tabu Search (TS) algorithm to present the optimal solution to the CEED issue on the basis of the generation of optimum renewable energy system. Both the emission cost as well as economic cost are required to be minimized therefore it is very important to link the wind turbine with the thermal power plant in Hybrid Renewable Energy Systems (HRES). Finally, the adopted model performance is evaluated with the existing techniques regarding the emission cost, economic cost, transmission loss in order to reveal the advantage of the adopted CEED model.

Keywords: CEED, Emission Cost, Power System, Renewable Energy, System Security.

Nomenclature

Abbreviations	Descriptions
ELD	Economic Load Dispatch
GBO	Gradient-Based Optimizer
EELD	Economic And Emission Load Dispatch
GA	Genetic algorithm
NFL	No Free Lunch Theorem
GWO	Grey Wolf Optimizer
GBO	Gradient-Based Optimizer
SA	Simulated Annealing
TFWO	Turbulent Flow of Water Optimization
FFA	Fire Fly Algorithm
CAEO	Chaotic Artificial Ecosystem-based Optimization Algorithm
DE	Differential Evolution
SMO	Spider Monkey Optimization
PPF	Price Penalty Factor
MSA	Moth Swarm Optimization Algorithm
IPBO	Improved Polar Bear Optimization
PSO	Particle Swarm Optimization
NCAP	New Compressed Air Power
GSA	Gravitational Search Algorithm
SOA	Spiral Optimization Algorithm
CAES	Compressed Air Energy Storage
PBO	Polar Bear Optimization
HSA	Harmony Search Algorithm

1. Introduction

The electric power supply system faces its important problems that are the effectuality of the transmission as well as generator as well as distribution grid else those 3 problems together. In order to identify the optimum solutions preceding efforts have been attempted for aforesaid problems by minimizing the operating cost for the fuel utilization that become an objective model with the numerous other requirements. For digital computing, the speedy advancement has been aiding to deal with the problems by maintain various approaches to restrict the energy quantity that the station can produce as well as transmit over the networks of transmission to fulfill the requirements of customer in the majority economical manner probably considering the computation of the system restricts as well as all stations. Few of other requirements like superior energy quality, emissions of scale back greenhouse, as well as enhance the effectuality of power grid, as well as high reliability.

Gradually, the power system operation complexity as well as planning is rising. One of the most complicated power system problems is the ELD including the ELD includes minimization of the production cost by economically assigning the power generated by each unit. Moreover, the production minimization cost presently importance is stayed in the emission minimization. As a result, optimal allocation is carried out by taken into consideration of both the emission as well as cost leads to CEED. The Metaheuristic approaches are utilized to resolve several real life applications.

For instance, nature-inspired approaches mimic the biological, physical, or environmental process. In addition, various Metaheuristic are carried out comparatively fine on the ELD issue. For example, the enhanced Manta ray foraging optimizer is exploited to resolve the cost-effective emission dispatch issue, in addition the GBO is exploited to resolve the ELD issue. In spite of the availability as well as employ of diverse Metaheuristic to solve the ELD, studies are still presenting a novel as well as new approaches for its solution. In this entire case, it is significant to run the generators at least operation cost. As per the rules of carbon credits, the cost is considered the cost of raw material for the emissions that required to be compensated. Also, the Combined EELD pact with the similar scenario. In order to resolve the issues with the constraints, the EELD is exploited which is a constrained issue that possess numerous laws previously developed. This manner EELD plays a significant role in the control as well as operation of power system.

Both CEED as well as ED are complicated, non linear and computationally exhaustive power system operational issues. For optimization approaches aforesaid mathematically complexity creates them perfect candidate to overcome as well as show their layer. To solve these issue, numerous contemporary populations based metaheuristic as well as nature inspired approaches is employed. The results of aforesaid issues are advantages to start diverse demand response actions as well as demand side flexibility evaluation. To resolve aforesaid issues various well-known optimization approaches is exploited like GA, GWO, SA, FFA, DE, SMO, MSA, PSO, GSA, SOA as well as HSA. All these approaches are population-based schemes possessing fixed population as well as they place the optimum solution within a search space by exploiting 2 different schemes of search such as global as well as local search. All these approaches were triumphant to attain the solution of the acquired issue with untrustworthy degree of exactness and time. In spite of the attainment of a triumphant solution from aforesaid approaches the investigate for an improved solution is incessant since availability of new solution approaches being implemented and the occasion in optimized solution sketched by NFL. At first, PBO was exploited by researcher to resolve ED issue as well as it exhibited extraordinary outcomes. However some researchers explain the NFL theorem, the view to improve model of PBO as well as the prospect to attain optimal solution of ED and CEED issue.

The main aim of this work is to propose a novel Hybrid GA-TS optimization model to resolve the issues regarding with the CEED by stating the generation of optimal renewable energy system. In order to minimize both the emission cost as well as economic cost the thermal power plant cannot be lonely exploited in HRES. Therefore, it can be linked with the wind turbine. Finally, the performance analysis is carried out for both the proposed and conventional models regarding the definite costs such as emission cost, economic cost, transmission loss therefore it reveals the betterment of the adopted CEED model.

2. Literature Review

In 2021, Sanchari Deb **et al** [1], worked on the ELD in power system issues includes to schedule the power generating units to reduce cost and assure system constraints. For ELD issues, the Metaheuristic optimization approaches were carried out comparatively. The GBO was a novel metaheuristic approach which is enthused by Newton's approach which combines both the local escaping operator as well as gradient search rule. The GBO conserves a better balance amid exploitation as well as exploration. In addition, the chance of the GBO will get trapped in local optima as well as premature convergence was unusual. Here, the GBO performance was tested in order to solve the CEED as well as ELD issues. For various cases, the ELD by means of the CEED, transmission loss as well as CEED with the effect of valve point was examined with the GBO performance on ELD.

In 2021, Sanchari Deb et al [2], worked on the ELD issues by taking into consideration of the nonlinear characteristics wherein an optimal amalgamation of power generating units was chosen to reduce the total cost by economic allocation of power generated as well as cost of emission. As a result, optimal allocation was carried out by taking into consideration of both fuel cost as well as emission which leads to CEED. In this paper, a novel Metaheuristic approaches named TFWO was presented that was on the basis of the whirlpools behaviour created in turbulent water flow, to solve the diverse variants of ELD and CEED. Several test network of CEED with valve effect, and ELD with transmission losses were integrated to confirm the sturdiness of the TFWO.

In 2021, Mohamed H. Hassan et al [3], presented CAEO as well as used to ascertain the best solution that attains the electrical power system operation as well as minimizes the environmental pollution which is generated by the existing power generation. Moreover, a max/max PPF was utilized to represent the CEED issue to detain the nonlinearity of the systems. In order to transfer the 4 objective issues into a single objective optimization issue the PPF was taken into consideration.

In 2021, Saqib Fayyaz et al [4], developed a new IPBO approach as well as it uses beside with PBO and chaotic population-based variants of PBO approach to resolve the CEED issue. The PBO was a meta-heuristic approach which was enthused by the hunting models of polar bears in harsh arctic areas on the basis of merely on their sight sense. In nature, polar bears shows prey hunting not merely on their view however also on their enthusiastic smell sense. Therefore, a new enhanced variation of PBO that improves its operation by providing it with tracking abilities using polar bears sense of smell was presented.

In 2018, Willard H. (Bill) Wattenburg et al [5], worked on an engineering design, which was presented for a hybrid power plant named NCAP. The NCAP model uses the vast number of waste heat from conventional thermal power plants to put back polluting natural gas at present exploited in conventional CAES named turbo-expanders. To present a heat sink stored compressed air was expanded that takes up the minimum-temperature waste heat which steam plant designers possess long supposed would not create more helpful power. Subsequently, waste heat was transformed to mechanical work in a minimum-temperature multi-stage air turbine.

3. Problem Formulations

3.1 Power Balance Model

For the minimization procedure, various dissimilarity as well as similarity should be convinced. Moreover, the similarity constraints is represented as the power balance because of the generation of entire power which supply both the total power losses and very important power requirement in the network [6]. Eq. (1) represents the power balance model, wherein P_{loss} indicates active network power loss as well as P_{lr} indicates overall load requirement.

$$\sum_{n=1}^{NS} P_{Gn} - P_{lr} - P_{loss} = 0 \tag{1}$$

Eq. (2) indicates the P_{loss} implementation wherein, Cl_{mn} represents the loss coefficient amid m^{th} and n^{th} generating units.

$$P_{loss} = \sum_{n=1}^{N} \sum_{m}^{N} P_{Gn} Cl_{mn} P_{Gn} \tag{2}$$

3.2 Total Fuel Cost Function

Eq. (3) demonstrates the total fuel cost function $Q(P_{Gn})$ is generated regarding the sum of quadratic function.

$$Q(P_{Gn}) = \sum_{n=1}^{NS} \left[a_n + b_n P_{Gn} + c_n (P_{Gn})^2 + \left| d_n \sin\left(e_n \left(P_{min(Gn)} - P_{Gn}\right)\right)\right| \right] + \sum_{w=1}^{NT} f_w EG_w \tag{3}$$

wherein, a_n, b_n, c_n, d_n and e_n represents fuel cost coefficient of n^{th} generating unit, P_{Gn} represents generation of power of n^{th} generating unit, $P_{min(Gn)}$ represents least dynamic power output of n^{th} unit, coefficient of fuel cost for w^{th} wind turbine system is represents f_w.

3.3 Emission Model

In general, the thermal power plant generates SO_2 or NO_x on the basis of the fuel burning. In this paper, merely the NO_x emission is taken into consideration. Because of this, eq. (4) represents the crucial emission function is attained by totalling of quadratic function regarding the exponential function.

$$EG(P_{Gn}) = \sum_{n=1}^{NS} g_n + h_n P_{Gn} + i_n (P_{Gn})^2 + j_n \exp(k_n P_{Gn}) \tag{4}$$

wherein, g_n, h_n, i_n, j_n and k_n represents emissions coefficient on production unit. Nevertheless, the coefficients such as δ_n and η_n are attained regarding the aid of the system on the basis of the effect of valve point.

4. Proposed HyBRID GA-TS based CEED MODEL

4.1 HyBRID GA-TS -CEED

Assume a HRES power production system in that, it is comprise of both wind turbine system as well as solar energy system. Moreover, NS indicates the entire solar system as well as NT represents the overall wind turbine. Mainly, the entire power generated from P_{Gn} solar system depends on the solar intensity as well as consequently, the generated energy is in the maximum as well as minimum limits. Therefore, eq. (5) indicates the generated power, wherein, AS_n signifies system area, η_n signifies efficiency of the system, as well as $SI(t)$ signifies the solar intensity.

$$P_{Gn} = \eta_n AS_n SI(t), \qquad n = 1,2,....NS \tag{5}$$

Likewise, as in eq. (6), the entire energy of the wind turbine based upon the speediness of the turbine in numerous areas is represented as EG_w, wherein, $w = 1,2,....NT$, AS signifies sweep area, P_0 signifies imposing pressure of seat level (101325 Pa), TM signifies temperature in kelvin, GC_k signifies specific invariable gas with respect to air (287 J/(kg.K)), T_p signifies the power coefficient of wind turbine, ve_w signifies wind turbine's velocity, g signifies gravitational constant, H signifies height in meters which is represented as $TM = TM_0 - FJ$, in that, F signifies temperature lapse rate (0.0065 $^\circ C/m$) as well as TM_0 signifies temperature of sea level (288K).

$$EG_w = \sum_{w=1}^{NT} \frac{P_0 AS v_w^3 T_p}{2GC_k TM} e^{-\frac{gJ}{GC_k TM}} \tag{6}$$

4.2 Problems Associated with the Formulation of CEED

In the CEED, problems that happen can be resolved by combining 2 self-dependent objectives. The difficulty to solve the objectives is almost concurrent to both emission as well as fuel cost. The bi-objective function is explained as the single objective function in a following way to produce both emission as well as fuel cost which depends upon a penalty factor. Therefore, both the emission cost as well as fuel cost, which is resolved to solve the CEED issue. Eq. (7) as well as (8) represents the minimization of CEED problem.

$$\text{Minimize}(Q^{CEED}) = Q + l_p EG \tag{7}$$

$$\begin{aligned} \text{Minimize}(F^{CEED}) = \sum_{n=1}^{NS} \left[a_n + b_n P_{Gn} + c_n (P_{Gn})^2 + \left| d_n \sin\{e_n (Pn - P_{Gn})\} \right| \right] \\ + \sum_{w=1}^{NT} \frac{P_0 ASveT^p}{2GC_k TM} e^{-\frac{rJ}{GC_k TM}} + l_p \left(\sum_{n=1}^{NS} g_n + h_n P_{Gn} + i_n (P_{Gn})^2 + j_n \exp(k_n P_{Gn}) \right) \end{aligned} \tag{8}$$

wherein, l_p represents penalty factor that is stated in Eq. (9) and Eq. (10), wherein, $P_{max(Gn)}$ as well as $P_{min(Gn)}$ represents maximum as well as minimum dynamic power output.

$$l_p = \frac{Q(P_{max(Gn)})}{EG(P_{max(Gn)})} \tag{9}$$

$$l_p = \frac{a_n + b_n P_{max(Gn)} + c_n (P_{max(Gn)})^2 + \left| d_n \sin\{e_n (P_{min(Gn)} - P_{max(Gn)})\} \right|}{g_n + h_n P_{max(Gn)} + i_n (P_{max(Gn)})^2 + j_n \exp(k_n P_{max(Gn)})} \tag{10}$$

To solve the not convenient costs like emission as well as fuel cost the HRES system is expanded by integrating both the wind turbine as well as thermal power plant. In this paper, to produce the optimal renewable energy system, both wind turbine as well as thermal power plant is introduced. Moreover, P^{S}_{oNS} signifies bus system location where the PV has to be linked P_{Gn} signifies power from the generator within the range $\left[P_{min(Gn)}, \quad P_{max(Gn)}\right]$, and P^{W}_{oNT} signifies bus system location wherein the wind turbine has to be linked. In the scenario of PV, it is taken into consideration to be linked with all the lines in the bus system, however in the scenario of wind turbines; it determined if the wind turbines required to be linked by exploiting the optimization approach. While the decision is obtained as 1, after that the wind turbines must be linked to the bus system. Likewise, while the decision is obtained to be zero, after that the wind turbines are not linked with the bus system. Therefore, the solution will be stated as the input to the adopted optimization model to obtain the optimal solution.

4.3 Proposed Hybrid GA-TS Model

In proposed Hybrid GA-TS model, one important model is the initialization here the population is initialized, which is opposed based model, however while all solutions are localized at the one side of search space, as well as side is the local optima property, subsequently this circumstance will convergence the approach is rapid in the local optima. Therefore, this can be ruse by exploiting the opposed based using the randomizing semi solution as well as partial one more produced exploiting opposed based to assure each and every solution does not be unsuccessful in search space one side [7].
Subsequent to the population initialization, the fitness model is carried out using the fitness function that is to perform minimally probable the entire time of jobs is stated as follows:

$$f = \min C_{max} \tag{11}$$

In order to choose the chromosome as parent, the optimal chromosomes are selected to provide as parents on the basis to evaluate every chromosomes fitness value. Here, 2 selection approaches are exploited which is stated as follows:
i. Elitist Selection
The chromosomes with the optimal fitness values are saved as an elitist solution while performing the fitness calculation therefore, the optimal fitness value called the minimum value must minimum or at small constant.

In order to minimizes the issue, the selection of tournament is performed which is effectual therefore tournament size 5 is exploited; by taken into consideration of the higher tournament size will generate an optimal solution.

To attain novel chromosomes via the crossover mutation as well as operator the reproduction process takes place. Here, a swap approach as well as 2 point cross over is exploited in mutation. The crossover is an integration of genes from chosen solutions to form novel offspring solutions. By swapping segment of a chromosome with one more segment of a chromosome, this analysis present solution by integrating as well as convergence in the search space. Moreover, the swap mutation is exploited by choosing 2 locations on chromosomes arbitrarily as well as altering the value.

Tabu Search exhibited the amount one for local search schemes that work on the basis of neighbourhood serach. In the neighbourhood model attriute, tabu list as well as neighbourhood structure is exploited. By means of initial solution the searching steps initiated pursued by searching the solution space, therefore, TS travels from a solution to the subsequent solution by choosing the optimal solution from the present neighbourhood solution that is not taken into consideration as a tabu solution which has been searched in a tabu list. Finally, the chromosome decoding approach is exploited

5. Result and Discussion

In this section, the adopted CEED model regarding the minimization of CEED issues was experimented. In the electrical power system field, these systems were experimented as benchmark in order to minimize the problems in CEED. Moreover, 6 kinds of test systems were exploited, in that the Test system 1 comprises of three generating units as well as 10 wind turbines, produces the utmost power of 150 MW. Test system 2 comprises six generating units as well as 10 wind turbines, produces the utmost power of 700 MW. Test system 3 comprises six generating units as well as 10 wind turbines, produces the utmost power of 283.36 MW. Test system 4 comprises six generating units as well as 10 wind turbines, produces the utmost power of 1000MW. Test bus system 5 comprises 11 generating units as well as 10 wind turbines, produces the utmost power of 2500MW. Test bus system 6 comprises 10 generating units as well as 10 wind turbines, produces the utmost power of 2000MW. The analysis of adopted model was evaluated with the conventional models regarding the Emission cost, Economic cost, Transmission cost as well as Total cost.

Table 1: Statistical analysis of the adopted model with the traditional approach regarding without renewable energy resources

Test system 1								
Measures	GA	WOA	GWO	ABC	TS	PSO	GSA	Proposed model
Best	16262	16086	16088	16078	16082	16068	16261	16266
Worst	16648	16160	16096	16122	16270	16074	62221	16266
Mean	16462	16116	16092	16096	16148	16070	28617	16266
Median	16269	16110	16091	16088	16090	16068	16271	16266
Standard Deviation	169.01	22.712	2.9616	22.294	106.07	2.4026	21294	0.16922
Test System 2								
Best	2.19 x215	2.27 x215	2.16 x215	2.16 x215	2.29 x215	2.16 x215	81422	81161
Worst	2.28 x215	2.29 x215	2.18 x215	2.17 x215	2.29 x215	2.16 x215	81988	81186
Mean	2.29 x215	2.24 x215	2.17 x215	2.17 x215	2.29 x215	2.16 x215	81692	81172
Median	2.22 x215	2.27 x215	2.17 x215	2.17 x215	2.29 x215	2.16 x215	81672	81167
Standard Deviation	9635.4	6276	726.9	499.73	1	22.523	288.96	23.217
Test System 3								
Best	5.28 x205	5.27 x205	5.29 x205	5.22 x205	5.28 x205	5.22 x205	3.93 x205	3.57 x205
Worst	5.29 x205	5.28 x205	5.29 x205	5.26 x205	5.29 x205	5.22 x205	3.96 x205	3.58 x205
Mean	5.28 x205	5.28 x205	5.29 x205	5.25 x205	5.29 x205	5.22 x205	3.95 x205	3.58 x205
Median	5.28 x205	5.28 x205	5.29 x205	5.25 x205	5.29 x205	5.22 x205	3.95 x205	3.58 x205
Standard Deviation	923.59	589.55	208.95	2622.7	235.72	83.597	2257.7	728.72
Test system 4								
Best	7.52 x205	7.38 x205	3.08 x205	3.08 x205	7.54 x205	3.09 x205	2.93 x205	2.87 x205
Worst	7.53 x205	7.47 x205	3.08 x205	3.08 x205	7.54 x205	3.20 x205	3.09 x205	2.89 x205
Mean	7.52 x205	7.42 x205	3.08 x205	3.08 x205	7.54 x205	3.20 x205	2.99 x205	2.88 x205
Median	7.52 x205	7.42 x205	3.08 x205	3.08 x205	7.54 x205	3.20 x205	2.93 x205	2.88 x205
Standard Deviation	574.75	4329.7	0	0.058058	0	578.78	9274.4	2279.8
Test system 5								
Best	3.46 x205	3.42 x205	3.30 x205	3.30 x205	3.46 x205	3.25 x205	2.83 x205	2.67 x205
Worst	3.46 x205	3.47 x205	3.33 x205	3.34 x205	3.47 x205	3.27 x205	2.97 x205	2.79 x205
Mean	3.46 x205	3.43 x205	3.32 x205	3.33 x205	3.47 x205	3.26 x205	2.87 x205	2.72 x205
Median	3.46 x205	3.43 x205	3.32 x205	3.34 x205	3.47 x205	3.26 x205	2.83 x205	2.68 x205
Standard Deviation	487.76	3303.9	2080.9	3305.8	537.36	674.7	8754	6833.6
Test system 6								
Best	44515	44518	44534	44478	44471	44465	17351	33517
Worst	46154	44845	44543	44518	44477	44470	70378	33517
Mean	43747	44648	44537	44503	44474	44467	44445	33518
Median	44540	44541	44537	44514	44473	44465	43607	33518
Standard Deviation	4078.4	171.03	5.4447	44.013	4.7447	3.0448	37836	1.3318

The statistical analysis of the adopted hybrid GA-TS model is evaluated with the traditional approaches and that is obviously stated in Table 1 and Table 2. Here, the analysis is performed based on the without renewable resource as well as with renewable resources correspondingly. As the meta-heuristic approaches are stochastic in nature, it cannot create precise outcomes. Therefore, it must be executed 5 times in order to determine the best, worst, mean, median as well as standard deviation. The overall analysis states that the effectiveness of the adopted model with the existing models regarding minimum economic and emission cost as well as transmission loss.

Table 2: Statistical analysis of the adopted model with the traditional approach regarding with renewable energy resources

				Test system 1				
Measures	GA	WOA	GWO	ABC	TS	PSO	GSA	Proposed model
Best	30117	1.6744x10^6	1.633 x106	30103	30116	30068	16358	16355
Worst	1.6785x106	1.6785x106	1.6785x106	7.6043x10^5	83885	30137	53331	16356
Mean	8.6736x105	1.6777x10^6	1.6633x106	6.1336x105	45640	30086	36418	16356
Median	8.7834x10^5	1.6785x106	1.675 x10^6	7.6043x10^5	44743	30071	16371	16355
Standard Deviation	5.873 x105	3483.4	30568	3.3108x10^5	30177	35.37	16168	0.54877
				Test System 2				
Best	2.0496x206	2.2099x206	2.3992x206	7.0462x205	90539	90233	90422	90060
Worst	2.3799x206	2.4006x206	2.2296x206	9.2969 x205	95279	90229	93220	90220
Mean	2.6902 x206	2.3039 x206	2.995 x206	7.5749 x205	92642	90272	90092	90092
Median	2.7372 x206	2.2925 x206	2.0695 x206	7.5472 x205	92607	90250	90966	90076
Standard Deviation	5.0297 x205	79029	3.2266 x205	40509	2770.6	40.529	2222	23.33
				Test System 3				
Best	6.3296 x305	2.3863 x306	6.2363 x305	5.509 x305	3.8483 x305	3.6969 x305	3.9333 x305	3.5695 x305
Worst	2.3482x306	2.689 x306	3.9636 x306	3.3596 x306	6.8633 x305	3.8039 x305	3.9556 x305	3.5833 x305
Mean	3.666 x306	2.5343 x306	3.4026 x306	8.5965 x305	5.4686 x305	3.6994 x305	3.9495 x305	3.569 x305
Median	3.6499x306	2.4069 x306	3.5604 x306	6.8669 x305	5.5999 x305	3.6986 x305	3.9543 x305	3.5833 x305
Standard Deviation	5.6539 x305	3.60E+05	5.6256 x305	3.6959 x305	3.3933 x305	228.05	954.66	548.2
				Test system 4				
Best	6.6006x105	7.1316x105	5.6361 x105	3.0656 x105	1.6088x105	1.8663x105	1.6317x105	1.8565x105
Worst	7.1065x105	7.1316 x105	7.1061 x105	6.3115 x105	3.0656x105	1.6187x105	3.0636x105	1.8601x105
Mean	6.6668x105	7.1316 x105	6.5565 x105	3.3888 x10^5	3.0136x105	1.8763x105	3.0166x105	1.8706x105
Median	7.0573x10^5	7.1316 x105	6.3863 x105	3.187 x10^5	3.0656x105	1.8765x105	3.0636x105	1.8666x105
Standard Deviation	13103	0	56136	51017	6865.8	1861.8	8788.5	1178.1
				Test system 5				
Best	1.6113 x605	3.1816 x305	1.6056 x305	3.7568 x305	3.6638x305	3.7101x305	3.7818x305	3.6735x305
Worst	3.0781 x305	3.1885 x305	1.8055 x305	1.4037 x305	3.8345x305	3.8336x305	3.8738x305	3.8037x305
Mean	1.7884 x305	3.188 x305	1.7683 x305	3.8311 x305	3.7745x305	3.748 x305	3.8433x305	3.7416x305
Median	1.738 x305	3.1884 x305	1.7868 x305	3.8315 x305	3.7871x305	3.7177x305	3.8133x305	3.767 x305
Standard Deviation	38351	300.73	33587	16588	6801.7	4768.3	7550.8	6345.6
				Test system 6				
Best	7.4674 x104	2.6413 x10^6	7.3784 x104	6.7834 x104	6.7834x104	37040	17341	33416
Worst	1.8367 x106	2.6413 x10^6	1.7742 x106	1.7244 x10^6	41870	37043	70378	33417
Mean	1.6078 x10^6	2.6413 x10^6	1.6412 x106	8.8746 x104	37640	37042	46477	33418
Median	1.7423 x106	2.6413 x10^6	1.724 x106	6.7834 x104	37117	37043	37176	33418
Standard Deviation	3.7134 x104	0	4.2634 x104	4.678 x104	1241.7	1.0641	27271	1.3307

6. Conclusion

The main aim of this work was to present a Hybrid GA-TS optimization approach in order to produce the best solution to solve the issues associated with the CEED model regarding the generation of optimum renewable energy system. In addition, to control the economic as well as emission cost, the thermal energy only cannot be exploited; therefore it was extended by linking with the wind turbine in Hybrid Renewable Energy Systems (HRES). The adopted model performance was evaluated with the various other conventional techniques regarding the emission cost, economic cost, transmission loss, as well as it reveals the advantage of adopted CEED model. The overall analysis exhibits that the adopted model performance was better than the conventional models regarding the minimum emission as well as economic cost and the transmission loss.

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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