Applications of continuous ant colony optimization and multi-objective hybridized differential evolution for the best location of microcontroller-built FACTS techniques

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Abstract

A combination of rising energy demand and budgetary constraints on the construction of new power plants has led to overloading, excessive transmission of energy, significant loss, decreased energy quality, equality problems, include volt curve difficulties. In order to fix these issues Transmission networks may use Flexible AC Transmit System (FACTS) controllers. It therefore enhances both vigorous and sluggish enactment. To achieve the aforementioned goals, it is necessary to optimize the location, the kind and power of FACTS processors. In this work, a hybrid method called DE-CACO that combines distinct evolution (DE) and continuous ant colony optimization (CACO) has been used to maximize numerous targets, including the reduction of volt variation, loss, price, and line load indices. Three microprocessor-controlled FACTS controller, including the static VAR compensations (SVC), unified power flows controlling scheme (UPFC), and thyristors-controlled series compensators (TCSC), had been positioned on the IEEE 30 buses architecture in an ideal manner.

Key Words: FACTS, hybrids DE-CACO, cost reduction, IEEE 30 bus system, optimum allocations.

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Introduction

Increased energy consumption makes it more challenging to operate the power system. Additionally, the energy systems designers are under pressure from the system's economic and ecological concerns. When designing, the introduction of FACTS controller provides some respite to the designers [1]. The addition of FACTS controller can boost the system’s transfer

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capability [2], strengthen its security [3], reduce power losses, improve volt constancy, and control grid slack in intricate energy systems [4] [5]. However, in order to use the FACTS controllers efficiently, the kind, placement, and capacities should be properly specified. The thyristors-controlled series compensators, static VAR compensations, unified power flows controlling scheme, static synchronous serial compensation, and static compensation had all been the subject of frequent investigations in this area (STATCOM). The focus has switched to FACTS controllers as a result of developments in computing methods, Electronics with wireless connectivity, microprocessors, and microcontrollers. An earlier study was conducted to locate FACTS controllers appropriately using non-linear and hybrid integers non-linear coding. To accomplish the aforementioned goals, a fuzz systems implementation has been provided [6-9]. These traditional approaches have limitations including misleading local answers and complicated mathematical models. Metaheuristic techniques including to address the aforementioned issues, Genetic Algorithm (GA), particle swarm optimization, non-dominated genetic algorithm, modified non-dominated genetic algorithm, and Ant Colony Optimization (ACO) have all been employed [10]. Those methods were forceful, quick, and simple to put into practice. The majority of these issues have been resolved with a single goal.

By taking equal opportunities and unequal restrictions into account and using a hybrid DE-CACO algorithm, this study aims to minimize numerous aims at once, including voltage variance, setbacks, price, and for the problem of where to best place FACTS controller on an IEEE 30 bus architecture, use the line load factor.

Problem formulation

By applying hybrid DE-CACO to minimize objective functions (OFs) including volts variation, loss, price, and line load indices, SVC, TCSC, and UPFC have been assigned optimally in this work.

Equation (1) and (2) have been successful in minimizing both actual power loss and total voltage deviation (TVD). The voltages variation at each input bus must be kept to a minimal in order to get a suitable voltage index. The following must be done to reduce the TVD:

$$OF_1 = \mathrm{Min(TVD)} = \sum_{i=1}^{LB} \left| V_i - V^{ref} \right| \tag{1}$$

$$OF_2 = \mathrm{Min}(P_L) = \sum_{k=1}^{nl} g_k \left[V_i^2 + V_j^2 - 2V_iV_j\cos(\delta_i - \delta_j) \right] \tag{2}$$

Wherein,

TVD	total voltage deviation
PL	actually lost power
nl	number of lines
gk	kth line's conductivity
	and the potentials at the kth line's output buses i and j
Vref	a standard voltage (Vref = 1.0 pu)
LB	buses with loads

Reduced line congestion will result in a lower line loading index, which will bring the minimized voltage closer to the target value. It could make the system more secure.

$$OF_3 = \mathrm{Min(LL)} = \sum_j \mathrm{w}_j \left(\frac{S_j}{S_{j,amx}} \right)^2 \tag{3}$$

Wherein,

LL	loading lines
wj	line's weighing component j
Sj	clear electricity at the line j
Sj,amx	low energy at the line j

FACTS equipment design

In this research, the best allocation of flexible ac transmission controller such thyristors-controlled series compensators, static VAR compensations, and unified power flow controller is considered. The displaced energy factor may be estimated using a microprocessor.

SVC Design

Static VAR compensations is a good flexible ac transmission controller for distributing responsive energy at node. It also provides reciprocal compensation for capacitance and inductance. As a result, it may be used to provide reactive energy at a particular node. The SVC is situated in a certain node as

$$\Delta Q = Q_{SVC} \tag{4}$$

Wherein, ΔQ is size of SVC.

SVC's price factor had been presented as

$$Cost_{SVC} = 0.0003\,s^2 - 0.305\,s + 127.38 \quad (5)$$

Wherein, s is the SVC's useful boundaries.

The TCSC's design

The TCSC is a series compensator that boosts transitory dependability while normalizing power through wide variety. TCSC is typically used to manage a line's reaction to an overload and is equally adept at acting under various protocols. Reactive power compensation has been done in this work using TCSC [11].

The TCSC's cost function has been provided as

$$Cost_{TCSC} = 0.0015\,s^2 - 0.7130\,s + 153.75 \quad (6)$$

Modelling of UPFC

To make the real and reactionary energy permissible at a set price, UPFC has been used. The Newton-Raphson approach has been used to congruently change the load flow equations. By combining the load flow, the regulating parameters of the UPFC have been calculated. It can manage voltage, phase angle, and impedance all at once [12] [13]. Reactance, phase angle, and voltage are used to determine how much power flows through the line and are provided in equation (7).

$$P_{ij} = \frac{V_i V_j}{X_{ij}} \sin(\delta_i - \delta_j) \quad (7)$$

Equations has been used to determine the price of UPFC

$$Cost_{UPFC} = 0.0003\,s^2 - 0.2691\,s + 188.22 \quad (8)$$

Description about hybrid DE-CACO

The following list outlines the hybrid DE-CACO algorithm's stages.

1. Start Np entities, then compute the fitness's measures. Category the entities conferring towards its suitability.

2. Continue with step 4 if NG = m · Nrefresh (m = 1, 2 …) otherwise move on to stage 3. NG stands for the amount of performed progression generations.

3. The whole CACO search has made use of the excellent set, which includes Np/2 entities with aptness lower than other entities. The haphazardness and variety equation (25) has been reformatted as follows in order to increase

$$X_i = X_i + rand(0,1) \times (X_{bestindex} - X_i) \quad (9)$$

The appropriateness has been assessed. The remaining entities are still included in the excellent set. They have been used by DE to produce kid vectors. From the whole population, the two individuals xr1,G and xr2,G have been chosen. Each person has been graded according to how appropriate they are. The best person, Ibest, has thus been obtained.

4. The members of the praiseworthy set have used the mutation method.

$$V_{i,G+1} = X_{i,G} + F(X_{b,G} - X_{i,G}) + F(X_{r1,G} - X_{r2,G}), \quad 1 \le r_1 \ne r_2 \ne i \le N_p. \quad (10)$$

Wherein, the two indicated entities, xr1,G and xr2,G, were selected from the general population. The impressive set has been given the crossover and selection methods. The aptness has been assessed and the remaining people have been primed. Each person has been graded according to how appropriate they are. The best person, Ibest, has thus been obtained.

5. The best person, Ibest, has been the subject of a local search.

6. If the closure circumstances have occurred, stop; otherwise, move on to step 2. The combination of the two strategies has improved the capability of global search.

Results and discussion

There are 41 branches in the IEEE 30-buses test systems, and 6 generators buses are situated on buses 1, 2, 5, 8, 11, and 13. It has four branches at 6-9, 6-10, 4-12, and 27-28, as well as 24 load buses. Buses 10, 12, 15, 17, 20, 21 23, 24 and 29 have links to There are 41 transmitting connections in the systems, 9 reactive energy generators with a total capability of 5 MVAr, and otherpower sources. Bus voltage vary

between 0.95 and 1.1 p.u. The IEEE 30-buses systems is depicted in one line in Figure 1. FACTS controllers' basic settings were modified from [14] [15].

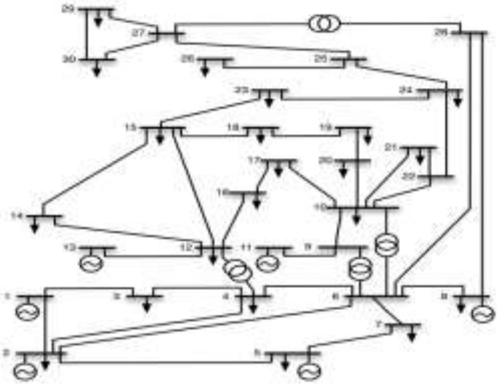

Figure 1. depicts the IEEE 30-buses trial setup on one lines.

On the IEEE 30 buses systems, the allocation of FACTS controllers like SVC, TCSC, and UPFC is accomplished under 5 different scenarios.

Instance 1: Absent FACTS controllers

Instance 2: SVC allocation

Instance 3: TCSC Allocation

Instance 4: UPFC allocation

Instance 5: Allocations of thyristors-controlled series compensators, static VAR compensations, and unified power flow controller.

According to the four separate multi-objective Condition listed below, the results have been retrieved.

Conditions 1: MOF1 = Minimum (OF1 + OF2)

Conditions 2: MOF2 = Minimum (OF2 + OF3)

Conditions 3: MOF3 = Minimum (OF1 + OF3)

Conditions 4: MOF4 = Minimum (OF1 + OF2 + OF3)

The outcomes of conditions 1, 2, and 3 show that the hybrid DE-CACO, which simultaneously takes into account two OFs, has successfully reduced TVD, the LL index as well as real energy loss. Condition 4 has concurrently taken into account all three OFs. Table 2 has been presented with the condition 4 findings that were attained. It demonstrates that instance 5 yields the best outcomes. The tuned values for the TVD, loss, and LL indexes are 0.6478, 3.7872 pu, and 2.8147. For each situation, plots displaying case 5's convergence characteristics have been created. The resolution curve for condition 1 is shown in Figure 2. For OF1 and OF2, the highest readings of 0.6478 and 3.7839 pu had been chosen as examples. Figure 3 depicts the resolution curve for instance 5 of criterion 2 in a manner similar to that. It has been displayed for the optimal actualpower losses and LL index values of 2.4724 pu and 3.7876, respectively. For condition 3, TVD and LL index reduction produced the best outcomes, 0.2170 and 2.8018. Figure 4 depicts the convergence curve that was plotted for these values. In condition 4, It has been successful to simultaneously minimize OF1, OF2, and OF3. For condition 4, Figure 5 shows the ideal values as 0.6478, 3.7872 pu, and 2.8147 for the TVD real energy loss, LL index, and converging graphs.

Table 1. DE-CACO for minimizing TVD, actual energy loss, and the LL index .

Symbols	Instance 1	Instance 2	Instance 3	Instance 4	Instance 5
V_1	1.0492	0.9499	1.0239	1.0499	1.0798
V_2	1.0491	0.9979	0.9799	1.0399	1.0988
V_5	1.0499	1.0495	1.0158	0.9799	1.0789
V_8	1.0799	1.0109	1.0199	0.9795	0.9965
V_{11}	1.0198	1.0198	1.0199	1.0739	1.0799
V_{13}	1.0159	1.0591	1.0796	1.0495	0.9499
T_{11}	0.9998	0.9959	1.0581	1.0796	1.0839
T_{12}	1.0497	1.0497	1.0792	0.9798	0.9969
T_{15}	1.0161	1.0799	1.0796	0.9698	0.9859
T_{36}	1.0795	1.0799	0.9899	0.9498	0.9929
Q_{c10}	0	1.5199	2.1799	3.1495	2.4799
Q_{c12}	0	3.1497	2.1799	4.1498	3.1499
Q_{c13}	0	2.0492	1.8399	2.4798	3.4798
Q_{c17}	0	2.3987	2.0399	3.0849	3.2496
Q_{c20}	0	2.0796	2.8799	1.1479	2.1798
Q_{c21}	0	2.1798	2.0856	1.4868	3.1793
Q_{c23}	0	2.0798	2.7849	3.1878	3.0456
Q_{c24}	0	4.0191	2.1860	2.5498	3.1789
Q_{c29}	0	2.1793	1.1396	1.4799	2.0749
SVC locations	-	14.98	-	-	5.9
SVC sizes (pu)	-	14.1499	-	-	21.0489
SVC costs ($/kWh)	-	101.5799	-	-	88.1799
TCSC locations	-	-	28.9	-	6.99
TCSC sizes (pu)	-	-	-0.1775	-	-0.1399
TCSC costs ($/kWh)	-	-	135.8199	-	112.0499
UPFC locations	-	-	-	16.98	14.6

Table 1 shows the outcomes of a combination DE-CACO for minimizing TVD, actual energy loss, and the LL index at the same time.

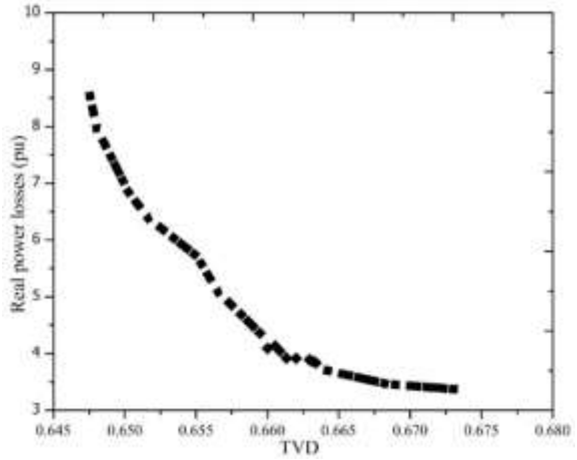

Figure 2. Conjunction chart for spontaneous total voltage deviation and actual power loss reduction.

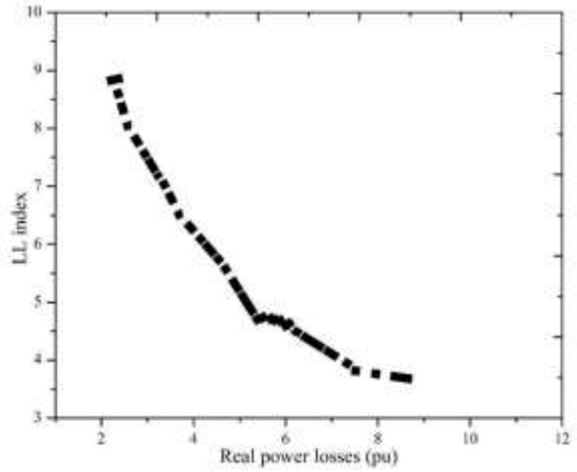

Figure 3. Conjunction chart for spontaneous true energy losses reduction and LL indices.

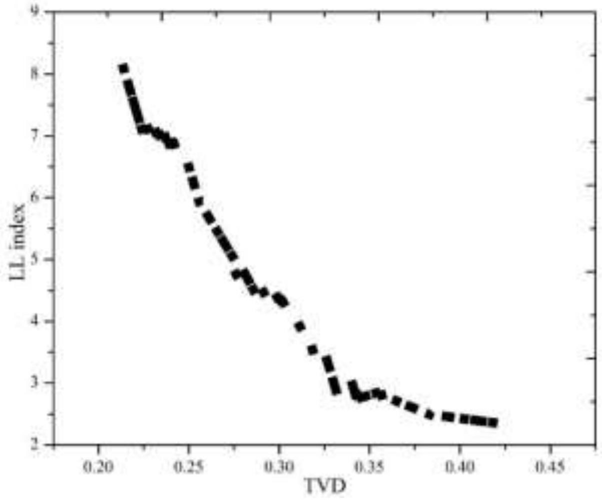

Figure 4. Convergence charts for simultaneous TVD and LL index lowering

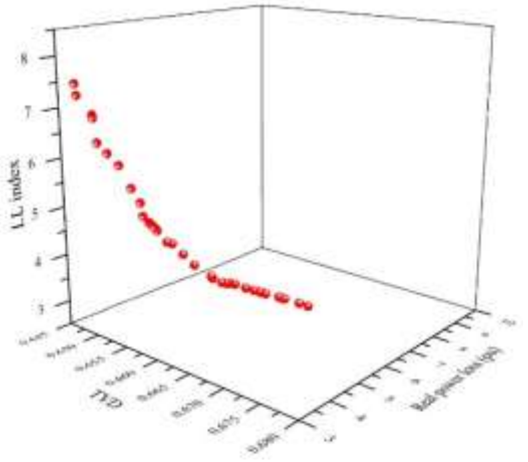

Figure 5. Convergence charts for concurrent TVD, actual energy loss, and LL index reduction

Conclusion

In this study, flexible ac transmission system controllers including thyristors-controlled series compensators, static VAR compensations, and unified power flow controller have been distributed over the IEEE 30 bus system while taking equality and inequality requirements into consideration using hybrid DE-CACO. This helps to reduce voltage variation, loss, cost, and line load index. Different combinations of objective functions have been used to simulate and solve four multi-objective circumstances. The results show that the installation of unified power flow controller standardizes power flows, lowers energy loss, and boosts systems reliability. In comparison to traditional FACTS controllers, power losses and TVD has been greatly decreased and tremendous commercial advantages have been realized thanks to the UPFC being installed exactly where it should be. Additionally, by reducing the LL index and incorporating UPFC, system safety has been increased. The hybrid DE-effectiveness CACO's was noticeable throughout the simulated tests. Additionally, the recommended approach is quite successful in optimizing discrete multimodal, multi-objective, clearly limited systems.

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