Applicability of Optimization Algorithm

3.1 Implementation of proposed method

In order to explain the multi-objective functions, the hybrid KGMO-CSA is employed to allocate three FACTS devices in the best way possible. Generation cost, TVD, line loading, and actual power loss are among the multi-objective functions. The following is a description of the many objective functions:

Generation cost

The structure's active or reactive power production costs have a significant impact on the generation cost. The following equations (1) and (2), respectively, express the costs of active and reactive power generation.

$$Cost_a = \sum_{i=1}^{N_G} a_i P_{gi}^2 + b_i P_{gi} + c_i \quad (1)$$

$$Cost_r = \sum_{i=1}^{N_G} a_i Q_{gi}^2 + b_i Q_{gi} + c_i \quad (2)$$

where, $Cost_a$ and $Cost_r$ are the active and reactive power production cost respectively; P_{gi} and Q_{gi} are the real and reactive power respectively; N_G states the number of Generators present in the system. The cost coefficients are denoted as a_i , b_i and c_i respectively.

- **Total voltage deviation**

The voltage gap amongst the reference voltage and the bus voltage typically represents the total voltage variation. Less voltage gap means a lower voltage deviation for the system. The TVD is defined by equation (3) as follows:

$$TVD = \sum_{i=1}^{N_L} \left|(V_i - V_{ref})\right| \quad (3)$$

where the amount of load bus is N_L; V_i and V_{ref} specifies the load bus voltage and reference voltagerespectively.

- **Line loading**

To maximise power flow within a certain range and lessen line overload in the transmission system, line loading minimization is used. The power flow gap amongst the actual value and the limit value is reduced by line loading. Equation represents line loading (4).

$$LL = \sum_{i=1}^{N_L} (P_{ij}(t) - P_{ijmax})^2 \quad (4)$$

where P_{ij} and P_{ijmax} signify the power flow at all line and maximum power flow boundary respectively;and t represents the time duration.

- **Real power loss**

Due to the interaction between the generator and demand node, the actual and reactive power are generated at the transmission line. The following equation describes the goal of a decrease in real power loss (Plossss) at transmissions lines (5).

$$P_{loss} = \sum_{i=1}^{L} G_{ij}(V_i^2 + V_j^2 - 2V_iV_j\cos(\delta_i - \delta_j)) \quad (5)$$

where L specifies the total number of transmission lines; the voltage magnitude in i^{th} and j^{th} bus is V_i and V_j respectively; the conductance of line i-j is G_{ij}; voltage angle of i^{th} and j^{th} bus is δ_i and δ_j correspondingly;

3.2 KGMO-CSA HYBRID

FACTS strategies are initially located in the system's various positions, and the behavior of the system is experiential both with and exclusive of FACTS devices. By analyzing the active and reactive power flows in the network, the location where the FACTS devices are to be placed is determined. After that, hybrid KGMO-CSA is employed to calculate the FACTS devices' magnitudes. The result obtained demonstrates the enormous benefits of hybrid KGMO-CSA-based allocation of FACTS devices in terms of real power losses, stability, and cost.

When compared to current techniques, the suggested KGMO-CSA achieves significant power losses and voltage stability in every situation. This hybrid KGMO-CSA approach makes use of both the KGMO and CSA algorithms to arrange FACTS devices optimally. The SVC, TCSC, and UPFC are already described in Section 3 in great depth. The hybrid KGMO-CSA method also assesses the several objectives in accordance with their optimal arrangement.

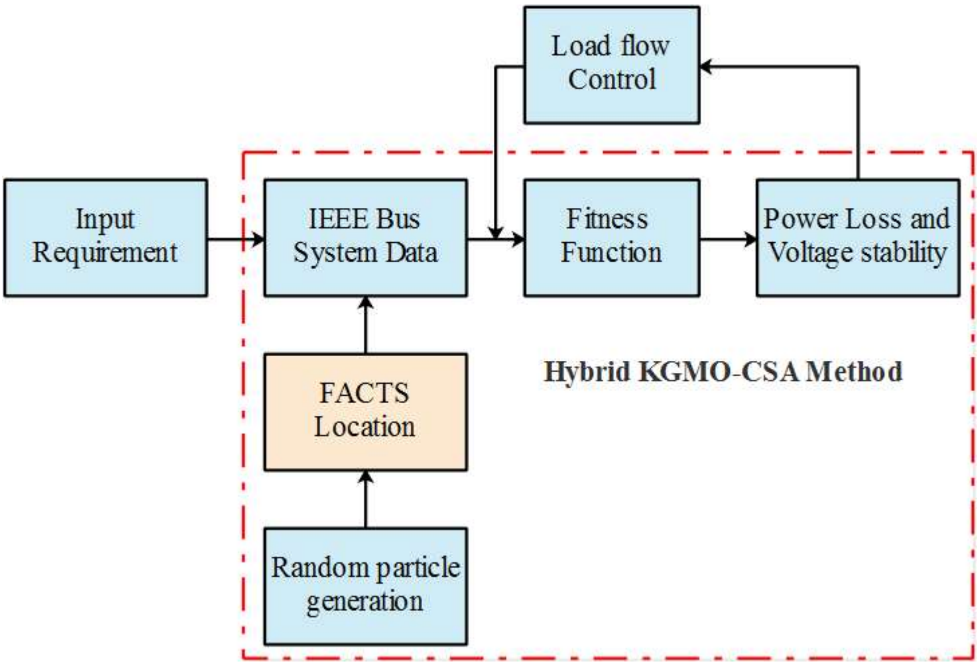

Figure 3.1 Block diagram for the system

The multi objects TVD, power loss, line loading, and the price of FACTS equipment are a few examples. The first step outlines the necessary inputs for the standard bus data from channels 14, 30, and 57. Next, distribute the FATCS devices at random to evaluate the voltage stability and power loss. For the best positioning of FACTS devices, a hybrid KGMO-CSA is introduced in the following stage. The best locations for the devices have been discovered using this KGMO-CSA. The voltage profile can then be improved, and power losses can be decreased by strategically installing the FACTS on a particular bus.

3.2.1 Kinetic Gas Molecular Optimization Algorithm

A metaheuristic optimization technique called KGMO lived typically created based on how gas molecules behave.

The particles of the KGMO are considered for four different specifications that are position, kinetic energy, velocity, and mass.

- The position in addition to velocity of the gas molecule are considered based on the kinetic energy.
- The inputs specified to the KGMO are reactive and real power, bus voltage and losses. Additionally, the preliminary location and size of the FACTS devices are given along with the inputs that are randomly selected in the bus system. In this hybrid KGMO-CSA method, the inputs are considered as gas molecules.
- Consider, the KGMO has P number of particles and the location of the agent k in KGMO is stated in the following equation (1).

  $$Z_j = \left(z_j^1, \ldots .z_j^d, \ldots z_j^p\right) \qquad for\ (j = 1,2, \ldots .P) \tag{1}$$

  where, z_j^p specifies the kth agent position at dth dimension. Equation (2) provides the velocity of the agent k.

  $$V_j = \left(v_j^1, \ldots .v_j^d, \ldots v_j^p\right) \qquad for\ (j = 1,2, \ldots .P) \tag{2}$$

  where, v_j^p specifies the k^{th} agent velocity at d^{th} dimension.

  The motion of the gas molecules changes upon the Boltzmann circulation that specifies the velocity which is straight proportional to the kinetic energy of the molecule. The equation (3) articulates the kinetic energy of the gas molecule.

  $$k_j^d\ (r) = \frac{3}{2}\ PbT_j^d(r),\ K_j = \left(k_j^1, \ldots .k_j^d, \ldots .k_j^m\right) \quad for\ (j = 1,2, \ldots .P) \tag{3}$$

  where, b is Boltzmann constant, T_j^d specifies the k^{th}agent temperature at dimension d and period r.

  Equation (4) expresses the velocity of the gas molecule updated in each iteration.

  $$v_j^d(r+1) = T_j^d(r)wv_j^d(r) + E_1rand_j(r)\left(gbest^d - z_j^d(r)\right) + E_2rand_j(r)\left(pbest_j^d(r) - z_j^d(r)\right) \tag{4}$$

  where the best previous location of jth gas molecule is

  $$pbest_j = (pbest_j^1, pbest_j^2, \ldots ..pbest_j^p)$$

  and best previous location for all the gas molecules is

  $$gbest_j = (gbest_j^1, gbest_j^2, \ldots ..gbest_j^p).$$

  The inertia weight is w, a uniform random variable is $rand_j$ and the two acceleration coefficients are $E_1$and E_2.

Additionally, the position of the molecule is obtained based on the motion that is given in equation (5).

$$z_{r+1}^{j} = \frac{1}{2} a_j^d (r+1) r^2 + v_j^d (r+1) r + z_j^d (r) \quad (5)$$

where the acceleration of agent k in dimension d is a_j^d. The following equation (6) is used for determining the minimum fitness function.

$$pbest_j = f(z_j), \quad if\ f(z_j) < f(pbest_j)$$

$$gbest = f(z_j), \quad if\ f(z_j) < f(gbest) \quad (6)$$

3.2.2 Cuckoo search algorithm

The constraints existing in the CSA are labeled as follows: pa is stated as the discovery rate of alien eggs/explanations, n is stated as an total of nests or various solutions and λ is stated as levy coefficient.

The cuckoo subjectively selects the nest location to place the eggs by using Eq. (1) and (2).

$$X_{pq}^{gen+1} = X_{pq}^{gen} + S_{pq} \times Levy(\lambda) \times \alpha \quad (1)$$

$$Levy(\lambda) = \left| \frac{\Gamma(1+\lambda) \times sin\left(\frac{\pi \times \lambda}{2}\right)}{\Gamma\left(\frac{1+\lambda}{2}\right) \times \lambda \times S^{(\lambda-1)/2}} \right|^{1/\lambda} \quad (2)$$

where λ is a constant$(1 < \lambda \leq 3)$; α is a random number generated among $[-1,1]$; Γ is gamma function; S is step size (S > 0). The step size is obtained by using Eq. (3).

$$S_{pq} = X_{pq}^{gen} - X_{fq}^{gen} \quad (3)$$

where p, $f \epsilon \{1,2, \ldots, m\}$ and $q \epsilon \{1,2, \ldots, D\}$ are randomly chosen indexes, f is chosen randomly but its value must be different from p.

The host bird finds the cuckoo egg and selects the high-quality egg based on the probability which is expressed in Eq. (4).

$$pro_q = \left(\frac{0.9 \times fit_q}{\max(fit)}\right) + 0.1 \tag{4}$$

where fit_q is the fitness value of the solution; q is the proportionality index of the quality of an egg. The expression for structure a new nest is given at Eq. (22).

$$nest_q = X_{q,min} + rand(0,1) \times (X_{q,max} - X_{q,min}) \tag{5}$$

3.3 Problem formulation

The mixture KGMO-CSA is used for the optimal allocation of three FACTS strategies. SVC, TCSC and UPFC to solve the multi objective functions. The multi objective function includes generation cost, TVD, line loading and real power loss.

Parameter	**Values**
Population count (P_i)	50
Weighting factor (w)	1.3
Number of Gas particles	5
Temperature (T)	0.95 to 0.1
Discovery Rate (pa)	3
Number of Nest (n)	20
Step dimension (S)	0.1
Levy Coefficient (λ)	1.5
Maximum Iteration($iter_{Max}$)	200
Probability coefficient(pro)	0.1
Proportionality Index (q)	1

Table 3.1. Parameter description of KGMO-CSA

Procedure of optimal allocation of FACTS devices using KGMO and CSA

In this hybrid KGMO-CSA method, the CSA is combined into the KGMO because of the appropriate exploration and exploitation probability of CSA. Additionally, the KGMO offers less computational complexity in large dimensional space. This hybrid KGMO-CSA results in an optimal location and size for FACTS devices various IEEE bus system. The pseudo code for the hybrid KGMO-CSA is presented under.

PSEUDOCODE

Consider every molecule {
Repeat and modify every molecule till it fulfills entire parameters}
Do {
For every element {
Evaluate the fitness function
If the estimated fitness is improved over the previous best
Fix the recent assessment as best new value
}
}
For every element {
If the projected fitness is improved over the global value
Fix the recent value as new global best
}
Evaluate the kinetic energy for every molecule present in the system
Update the position and velocity of each particle
}
} while the conditions of limited error measure or more iterations count not accomplished
Objective function (), = (1,2.)
Produce preliminary population count of n host nests (P_i = 1, 2...n)
While t < Generation count

Randomly develop a cuckoo through Lévy dissemination;
Calculate its worth;
Randomly select a nest between n;
Calculate its worth;
Substitute j through new result;
End
A portion of poorer nests are neglected and fresh nest is made at
Find fresh position with the help of Lévy flights;
Save the finest result;
Order the results and discover the new best value;
End while