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True Power Loss Reduction by Chemical Reaction Optimization Algorithm

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ABSTRACT

In this paper Chemical Reaction Optimization (CRO) algorithm is proposed to solve the optimal reactive power problem. Molecules are encoded as candidate solution in the projected algorithm. Molecular structure (φ), potential energy (PY), kinetic energy (KE) and numerous crucial properties possessed by the Chemical Reaction Optimization (CRO) algorithm. With minimal potential energy (PE) reactants are leaning to unwavering product. Gaussian perturbations with reflection, half-total change, laws of conservation of energy are form as the prime operators in the Chemical Reaction Optimization (CRO) algorithm. In the evolution of the algorithm structure manage the least potential energy (PE). Potential energy (PE) is kept as the objective function of the analogous solution. Projected Chemical Reaction Optimization (CRO) algorithm has been tested in standard IEEE 14, 57, 300 bus systems. Simulation results indicate the better performance of the proposed algorithm in reducing the real power loss.

1. INTRODUCTION

T Reactive power problem plays a key role in secure and economic operations of power system. Optimal reactive power problem has been solved by a various type of methods [1-8]. Nevertheless numerous scientific difficulties are found while solving problem due to an assortment of constraints. Evolutionary techniques [9-21] are applied to solve the reactive power problem. In this paper Chemical Reaction Optimization (CRO) algorithm is proposed to solve the optimal reactive power Problem. CRO algorithm has productively solved many multifaceted problems and the optimal solution is better than assortment of intelligent algorithms. In this work regulate molecular structure and energy management has been utilized in the formulation of the algorithm. Candidate solution of reactive power flow problem is encoded as a molecule in Chemical Reaction Optimization (CRO) algorithm. Molecular structure (φ), potential energy (PE), kinetic energy (KE) are some numerous crucial properties possessed by the algorithm. Reactants are leaning to stable product with the minimal potential energy (PE) in the algorithm. Structure reaches the least potential energy (PE) in the evolution of the algorithm. In this work Chemical Reaction Optimization (CRO) algorithm has been tested in standard IEEE 14, 57, 300 bus systems. Simulation results indicate the better performance of the proposed algorithm in reducing the real power loss.

2. PROBLEM FORMULATION

Objective of the problem is to reduce the true power loss:

$$\mathbf{F = P_L = \sum_{k\in Nbr}\ g_k\left(V_i^2 + V_j^2 - 2V_iV_j cos\theta_{ij}\right)} \quad (1)$$

Voltage deviation given as follows:

$$\mathbf{F = P_L + \omega_v \times Voltage\ Deviation} \quad (2)$$

Voltage deviation given by:

$$\mathbf{Voltage\ Deviation} = \mathbf{\sum_{i=1}^{Npq}|V_i - 1|} \quad (3)$$

Constraint (Equality)

$$\mathbf{P_G = P_D + P_L} \quad (4)$$

Constraints (Inequality)

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

$$\mathbf{Q_{gi}^{min} \le Q_{gi} \le Q_{gi}^{max}, i \in N_g} \quad (6)$$

$$\mathbf{V_i^{min} \le V_i \le V_i^{max}, i \in N} \quad (7)$$

$$\mathbf{T_i^{min} \le T_i \le T_i^{max}, i \in N_T} \quad (8)$$

$$\mathbf{Q_c^{min} \le Q_c \le Q_C^{max}, i \in N_C} \quad (9)$$

3. CHEMICAL REACTION OPTIMIZATION ALGORITHM

Chemical Reaction Optimization (CRO) algorithm has been formulated to solve the reactive power optimization problem. Molecules are encoded as candidate solution in the projected algorithm. Molecular structure (φ), potential energy (PE), kinetic energy (KE) and numerous crucial properties possessed by the Chemical Reaction Optimization (CO) algorithm. With minimal potential energy (PE) reactants are leaning to unwavering product. In the evolution of the algorithm structure manage the least potential energy (PE). Potential energy (PE) is kept as the objective function of the analogous solution and it symbolized by φ as follow,

$$PE(\varphi) = f(\varphi) \quad (10)$$

The molecule class algorithm can be written as
Category Molecule
Characteristics:
Molecular structure (ω), PE (potential energy), KE (kinetic energy), Number of Hit, Minimum Structure, Minimum PE, Minimum number of Hit
Technique:
Molecule () \\ ctor
{
Arbitrarily engender ω in the solution space
Potential energy ← *f (ω)*
Kinetic energy ← *preliminary value of kinetic energy*
Number of Hit ← 0
Minimum Structure ← *ω*
Minimum potential energy ← *PE*
Minimum number of Hit
← 0
}
On wall Ineffective Collision ( )
Decomposition ( )
Intermolecular Ineffective Collision ( )
Synthesis ( )
End class

Collision is the main cause of the chemical reaction. Four elementary reactions: molecule collision, decomposition, molecular collision and synthesis are form as the basics of the algorithm. Pop size ( ), Molecule Collusion, KE Loss Rate, Initial KE, buffer, γ, δ are basic parameters of the algorithm. Gaussian perturbations with reflection, half-total change, laws of conservation of energy are form as the prime operators [22] in the Chemical Reaction Optimization (CRO) algorithm;

$$\sum_{k=1}^{k=popsize\ (t)} \boldsymbol{PE_{\omega}(k) + KE_{\omega}(k) + buffer(k) == C} \quad (11)$$

$$\sum_{k=1}^{k=C} \boldsymbol{PE_{\omega} + KE_{\omega} \geq \sum_{k=1}^{k=l} PE'_{\omega}} \quad (12)$$

By on-wall ineffective collision, decomposition, inter-molecular ineffective collision and synthesis operation algorithm has been employed.

Molecular wall operation: In a single molecule a small change in the molecular structure in the independent space. The equivalent of the target function under the condition of conservation of energy in any adjacent area search is $PE'_{\varphi} = f(\varphi')$.

For illustration:

$$\boldsymbol{out\ (m,n) = in + random\ n} \quad (13)$$

Algorithm for Molecular wall ineffective collusion
Input: molecule M_{ω}
$\omega \leftarrow N(\omega)$
$PE_{\omega'} \leftarrow f(\omega')$
$Number\ of\ Hit_{\omega} \leftarrow Number\ of\ Hit_{\omega} + 1$
If *PEω + KEω* ≥ $PE_{\omega'}$ then
Engender *a* ∈ [*KE Loss Rate, 1*]
$KE_{\omega'} \leftarrow (PE\omega - PE_E + KE\omega) \times a$
Buffer ← *buffer* + $(PE\omega - PE_{\omega'} + KE\omega) \times (1 - a)$
$\omega \leftarrow \omega'$
PEω ← $PE_{\omega'}$
KEω ← $KE_{\omega'}$
If *PEω* < *Minimum PEω* then
Minimum Structure ω ← *ω*
Minimum PEω ← *PEω*
Minimum number of Hitω ← *Number of Hitω*
End if
End if

Decomposition operation: when a molecule encounters a collision and then it decomposes into two molecules. It is equated with the following,

$$\boldsymbol{f(\varphi) \geq f(\varphi'_1) + f(\varphi'_2)} \quad (14)$$

Algorithm for decomposition
Input: molecule *Mω*
Generate $M_{\omega'_1}\ and\ M_{\omega'_2}$
Acquire $\omega'_1\ and\ \omega'_2$ from *ω*
$PE_{\omega'_1} \leftarrow f(\omega'_1)$ and $PE_{\omega'_2} \leftarrow f(\omega'_2)$
If *PEω + KEω* ≥ $PE_{\omega'_1} + PE_{\omega'_2}$ then
Edec ← *PEω + KEω* − $(PE_{\omega'_1} + PE_{\omega'_2})$
Go to engender *δ*3 ∈ [0, 1]
Else
Engender *δ*1, *δ*2 ∈ [0, 1]
Edec ← *PEω + KEω + δ*1*δ*2 × *buffer* − $(PE_{\omega'_1} + PE_{\omega'_2})$
If *Edec* ≥ 0 then
Buffer ← *buffer* × *(*1 − *δ*1*δ*2*)*
Engender *δ*3 ∈ [0, 1]
($KE_{\omega'_1} \leftarrow Edec \times \delta 3$ and $KE_{\omega'_1} \leftarrow Edec \times (1 - \delta 3)$
$minimum\ structure_{\omega'_1} \leftarrow \omega'_1$ and $minimum\ structure_{\omega'_2} \leftarrow \omega'_2$
$MinimumPE_{\omega'_1} \leftarrow \omega'_1$ and $MinimumPE_{\omega'_2} \leftarrow \omega'_2$
Obliterate *Mω*
Else
Number of Hitω ← *Number of Hitω* + 1
Obliterate *M* ω'_1 and *M* ω'_2
End if
End if

Inter-molecular ineffective collision operation: when two molecules collide with each other, then it dislocate the result, *out*1 (*m, n*) = *in*2 (*m, n*), *out*2 (*m, n*) = *in*1 (*m, n*) (*out* (*m, n*) is 2-dimensional output molecule, when *in (m, n)* is 2-dimensional input molecule).

Algorithm for intermolecular Ineffective Collision
Input: molecules *Mω*1 and *Mω*2
$\omega'_1 \leftarrow N(\omega 1)$ and $\omega'_2 \leftarrow N(\omega 2)$
$PE_{\omega'_1} \leftarrow f(\omega'_1)$ and $PE_{\omega'_2} \leftarrow f(\omega'_2)$
Number of Hitω$_1$ ← *Number of Hitω*$_1$ + 1 and *Number of Hitω*$_2$ ← *Number of Hitω*$_2$ + 1
Einter ← (PEω1+ PEω2+ KEω1+ KEω2) − $(PE_{\omega'_1} + PE_{\omega'_2})$
If *Einter* ≥ 0 then
Generate *δ*4 ∈ [*0, 1*]
$KE_{\omega'_1} \leftarrow Einter \times \delta 4$ and $KE_{\omega'_2} \leftarrow Einter \times (1 - \delta 4)$
$\omega 1 \leftarrow N(\omega'_1)$ and $\omega 2 \leftarrow N(\omega'_2)$
*PEω*1← *PE* ω'_1 and *PEω*2← *PE* ω'_2
*KEω*1← *KE*ω'_1 and *KEω*2← *KE*ω'_2
If *PEω*1 < *MinPEω*1 then
*Minimum Structω*1← *ω*1
*Minimum PEω*1← *PEω*1
*Minimum number of Hitω*1← *Number of Hitω*1
End if
If *PEω*2 < *MinPEω*2 then
*Minimum Structω*2 ← *ω*2
*MinimumPEω*2 ← *PEω*2

*MinimimHitω*2 ← *Number of Hitω*2
End if
End if

Synthesis operation: it is a process of exactly opposite of decomposition. It merges two molecules into one molecule using *out* (*m*, *n*) = *in*1 (m, *n*) or *out* (*m*, *n*) = *in*2 (*m*, *n*).

Algorithm for synthesis operation
Input: molecules *Mω*1 and *Mω*2
Generate $M\omega'$
Acquire ω' from *ω*1 and *ω*2
$PE_{\omega'} \leftarrow f(\omega')$
If $PE\omega1 + PE\omega2 + KE\omega1 + KE\omega2 \geq PE\ \omega'$then
$KE\omega' \leftarrow (PE\omega1 + PE\omega2 + KE\omega1 + KE\omega2) - PE\omega'$
Minimum Structure $\omega \leftarrow \omega'$
Minimum PE $\omega_1' \leftarrow PE\omega'$
Obliterate *Mω*1 and *Mω*2
Else
*Number of Hitω*1← *Number of Hitω*1+ 1 and *Number of Hitω*2← *Number of Hitω*2+ 1
Obliterate ω'
End if
a. Begin
b. fundamental parameters are initialized
c. adjudicator random ( ) > Molecule Collusion
d. adjudicator $KE \leq \delta$ when step (c) fulfilled
e. synthesis operation done when step (d) fulfilled
f. Inter-molecular ineffective collisions will take place
g. Synthesis operation is done when step (d) not fulfilled
h. do molecule selection procedure when if step (c) not fulfilled
i. adjudicator *Number of Hit-Minimum number of Hit* > γ
j. Do on-wall ineffective process
k. subsequently decomposition process has to be done
l. Test for minimum potential energy (PE)
m. When Current potential energy (PE) <parameter potential energy (PE) limit satisfied, then return to step (c)
n. End

4. SIMULATION RESULTS

At first in standard IEEE 14 bus system the validity of the proposed algorithms has been tested & comparison results are presented in Table 1. Real power loss has been considerably reduced & vital parameters are within the limits.

Table 1. Comparison of real power loss

Control variables	ABCO [23]	IABCO [23]	CRO
V1	1.06	1.05	1.03
V2	1.03	1.05	1.01
V3	0.98	1.03	1.00
V6	1.05	1.05	1.01
V8	1.00	1.04	0.90
Q9	0.139	0.132	0.100
T56	0.979	0.960	0.900
T47	0.950	0.950	0.900
T49	1.014	1.007	1.000
Ploss (MW)	5.92892	5.50031	4.10212

Then the Performance of the projected algorithm has been validated by tested in standard IEEE 57 bus system [24]. Total active and reactive power demands in the system are 1248.23 MW and 334.16 MVAR. Generator data the system is given in Table 2. The optimum loss comparison is presented in Table 3.

Table 2. Generator data

Generator No	Pgi minimum	Pgi maximum	Qgi minimum	Qgi maximum
1	25.00	50.00	0.00	0.00
2	15.00	90.00	-17.00	50.00
3	10.00	500.00	-10.00	60.00
4	10.00	50.00	-8.00	25.00
5	12.00	50.00	-140.00	200.00
6	10.00	360.00	-3.00	9.00
7	50.00	550.00	-50.00	155.00

Table 3. Comparison of losses

Parameter	CLPSO [26]	DE [25]	GSA [25]	OGSA [27]	SOA [26]	QODE [25]	CSA [28]	CRO
PLOSS (MW)	24.5152	16.7857	23.4611	23.43	24.2654	15.8473	15.5149	13.1264

Then the performance of the proposed Algorithm has been tested in standard IEEE 300 bus system [24]. Table 4 shows the comparison of real power loss obtained after optimization.

Table 4. Comparison of real power loss

Parameter	EGA [29]	EEA [29]	CSA [28]	CRO
PLOSS (MW)	646.2998	650.6027	635.8942	623.2196

5. CONCLUSION

In this paper, Chemical Reaction Optimization (CRO) algorithm successfully solved optimal reactive power problem. Candidate solution of reactive power flow problem is encoded as a molecule in Chemical Reaction Optimization (CO) algorithm. Gaussian perturbations with reflection, half-total change, laws of conservation of energy are formed as the prime operators in the Chemical Reaction Optimization (CRO) algorithm Search of the optimal solution has been improved. Projected Chemical Reaction Optimization (CRO) algorithm has been tested in standard IEEE 14, 57, 300 bus systems. Simulation results indicate the better performance of the proposed algorithm in reducing the real power loss.

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