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Diminution of Active Power Loss by Communal Expressive Optimization Algorithm

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Abstract

Human society is a multifarious collection which is more effectual than other animal groups. Consequently, if one algorithm imitates the human society, then the efficiency may be healthier than other swarm intelligent algorithms which are stimulated by other animal groups. In this paper Communal Expressive (CE) Optimization Algorithm has been utilized to solve reactive power problem. The key feature of solving Optimal Reactive Power Problem is to reduce the real power loss and to maintain the voltage profile within the specified limits. The proposed Communal Expressive (CE) Optimization Algorithm has been authenticated, by applying it in standard IEEE 118 & practical 191 bus test systems. The results have been compared to other standard methods and the projected algorithm converges to finest solution.

***Keywords**: ;* Optimal reactive power, Transmission loss, Communal Expressive, Optimization algorithm.

1. Introduction

Numerous algorithms are employed to solve the Reactive Power problem. Dissimilar types of arithmetical methods like the gradient method [1-2], Newton method [3] and linear programming [4-7] have been previously used to solve the optimal reactive power problem. The voltage stability problem plays a central role in power system planning and operation [8].Evolutionary algorithms such as genetic algorithm, Hybrid differential evolution algorithm, Biogeography Based algorithm, a fuzzy based approach, an improved evolutionary programming [9-15] have been already utilized to solve the reactive power flow problem In [16-18] different methodologies are effectively handled the optimal power problem. In [19-20], a programming based approach and probabilistic algorithm is used to solve the optimal reactive power problem.In Communal Expressive (CE) Optimization Algorithm, every individual symbolize one person, while all points in the problem space which build the grade of the society. In this realistic world, all individuals aspire to look for the superior social position. Consequently, they will converse through cooperation and contest to augment individual status, while the one with uppermost score will succeed and yield as the concluding solution. In the research, Communal Expressive (CE) Optimization Algorithm has an extraordinary performance in terms of accurateness and convergence speed [21-25]. In this study Communal Expressive (CE) Optimization Algorithm has been utilized to solve the reactive power Problem. This Communal Expressive (CE) Optimization Algorithm is applied to obtain the optimal control variables so as to minimize the real power loss the system. The performance of the proposed Communal Expressive (CE) Optimization Algorithm has been tested in standard IEEE 118 & practical 191 bus test systems and the results are compared with standard algorithms.

2. Research Method

2.1. Problem Formulation

The Optimal Power Flow problem has been considered as general minimization problem with constraints, and can be mathematically written as, Minimize f(x, u) (1)

Subject to g(x,u)=0 (2)
and
$h(x,u) \leq 0$ (3)

Where f(x,u) is the objective function. g(x.u) and h(x,u) are respectively the set of equality and inequality constraints. x is the vector of state variables, and u is the vector of control variables.

The state variables are the load buses (PQ buses) voltages, angles, the generator reactive powers and the slack active generator power:

$$x = \left(P_{g1}, \theta_2, .., \theta_N, V_{L1}, ., V_{LNL}, Q_{g1}, .., Q_{gng}\right)^T \quad (4)$$

The control variables are the generator bus voltages, the shunt capacitors and the transformers tap-settings:

$$u = \left(V_g, T, Q_c\right)^T \quad (5)$$

or

$$u = \left(V_{g1}, \dots, V_{gng}, T_1, .., T_{Nt}, Q_{c1}, .., Q_{cNc}\right)^T \quad (6)$$

Where Ng, Nt and Nc are the number of generators, number of tap transformers and the number of shunt compensators respectively.

2.2. Objective Function

2.2.1. Active power loss

The goal of the reactive power dispatch is to minimize the active power loss in the transmission network, which can be mathematically described as follows:

$$F = PL = \sum_{k \in Nbr} g_k \left(V_i^2 + V_j^2 - 2V_iV_j cos\theta_{ij}\right) \quad (7)$$

or

$$F = PL = \sum_{i \in Ng} P_{gi} - P_d = P_{gslack} + \sum_{i \neq slack}^{Ng} P_{gi} - P_d \quad (8)$$

Where g_k : is the conductance of branch between nodes i and j, Nbr: is the total number of transmission lines in power systems. P_d: is the total active power demand, P_{gi}: is the generator active power of unit i, and P_{gsalck}: is the generator active power of slack bus.

2.2.2. Voltage profile improvement

For minimization of the voltage deviation in PQ buses, the objective function formulated as:

$$F = PL + \omega_v \times VD \quad (9)$$

Where ω_v: is a weighting factor of voltage deviation.
VD is the voltage deviation given by:

$$VD = \sum_{i=1}^{Npq} |V_i - 1| \quad (10)$$

2.2.3. Equality Constraint

The equality constraint g(x,u) of the ORPD problem is represented by the power balance equation, where the total power generation must envelop the total power demand and the power losses:

$$P_G = P_D + P_L \quad (11)$$

2.2.4. Inequality Constraints

The inequality constraints h(x,u) imitate the limits on components in the power system as well as the limits created to guarantee system security. Upper and lower bounds on the active power of slack bus, and reactive power of generators:

$$P_{gslack}^{min} \le P_{gslack} \le P_{gslack}^{max} \quad (12)$$

$$Q_{gi}^{min} \le Q_{gi} \le Q_{gi}^{max}, i \in N_g \quad (13)$$

Upper and lower bounds on the bus voltage magnitudes:

$$V_i^{min} \le V_i \le V_i^{max}, i \in N \quad (14)$$

Upper and lower bounds on the transformers tap ratios:

$$T_i^{min} \le T_i \le T_i^{max}, i \in N_T \quad (15)$$

Upper and lower bounds on the compensators reactive powers:

$$Q_c^{min} \le Q_c \le Q_C^{max}, i \in N_C \quad (16)$$

Where N is the total number of buses, N_T is the total number of Transformers; N_c is the total number of shunt reactive compensators.

2.3. Communal Expressive (CE) Optimization Algorithm

All people will do their work hardly in the human society, to enhance their social position. To attain this purpose, people will try their bests to discover the path so that supplementary social wealth's can be remunerated. Stimulated by this happening, a new population-based swarm, Communal Expressive (CE) Optimization Algorithm has been projected and in which each individual imitate a virtual person whose choice is steer by his passion. In Communal Expressive (CE) Optimization Algorithm, every individual symbolize a realistic person in every generation selection is based on his behaviour according to the analogous emotion index. Following that the behaviour is done, a status value is feedback from the society to validate whether this deeds is right or not. If this selection is right, the emotion index of the person will amplify or else it will reduce.

All individual's emotion indexes are set to 1 in first step, with this value; they will choice the following behaviour:

$$\vec{Y}_j(1) = \vec{Y}_j(0) \oplus Manner_1 \quad (17)$$

Where $\vec{Y}_j(1)$ symbolize the social position of j's individual in the initialization period, the analogous fitness value is indicated as the society status. Symbol ⊕ means the operation, in this paper, we only take it as addition operation +. Since the emotion index of j is 1, the movement phase Manner1 is defined by:

$$Manner_1 = -g_1 \cdot rand_1 \cdot \sum_{W=1}^{L} \left(\vec{Y}_W(0) - \vec{Y}_j(0)\right) \quad (18)$$

Where g_1 is a parameter used to control the emotion changing size, $rand_1$ is one random number sampled with uniform distribution from interval (0,1). The worst L individuals are selected to provide a reminder for individual j to avoid the wrong behaviour. In the initialization period, there is small emotion affection, therefore, in this period, there is a little fine experience can be referred, so, $Manner_1$ simulates the affection by the wrong experiences.

In t generation, if individual j does not obtain one better society status value than previous value, the j's emotion index is decreased as follows:

$$CI_j(t+1) = CI_j(t) - \Delta \quad (19)$$

Where Δ is a predefined value, and set to 0.05, this value is coming from experimental tests. If individual j is rewarded a new-fangled status value which is the best one among all previous iterations, the emotion index is reset to 1.0:

$$CI_j(t+1) = 1.0 \qquad (20)$$

If $CI_j(t+1) > 1.0$ then $CI_j(t+1) = 0.0$.

In order to imitate the behaviour of human, three kinds of manners are calculated, and the subsequent behaviour is changed according to the following cases:

If $CI_j(t+1) < TH_1$, then

$$\vec{Y}_j(t+1) = \vec{Y}_j(t) \oplus Manner_2 \qquad (21)$$

If $H_1 \leq CI_j(t+1) < TH_2$, then

$$\vec{Y}_j(t+1) = \vec{Y}_j(t) \oplus Manner_3 \qquad (22)$$

Otherwise

$$\vec{Y}_j(t+1) = \vec{Y}_j(t) \oplus Manner_4 \qquad (23)$$

Parameters TH_1 and TH_2 are two thresholds aiming to restrict the dissimilar behaviour manner. For Case1, because the emotion index is too small, individual j prefers to imitate others triumphant experiences. Therefore, the symbol Manner2 is updated with:

$$Manner_2 = G_3 \cdot rand_3 \left(\vec{Y}_{jbest}(t) - \vec{Y}_j(t)\right) + G_2 \cdot rand_2 \cdot \left(\overrightarrow{status}_{best}(t) - \vec{Y}_j(t)\right) \qquad (24)$$

Where $\overrightarrow{status}_{best}(t)$ represent the most excellent society status position obtained from all people previously.

$$\overrightarrow{status}_{best}(t) = \arg min \left\{f\left(\vec{Y}_W(h)|1 \leq h \leq t\right)\right\} \qquad (25)$$

$Manner_3$ is defined as

$$Manner_3 = g_3 \cdot rand\ _3 \cdot \left(\vec{Y}_{j,best}(t) - \vec{Y}_j(t)\right) + g_2 \cdot rand\ _2 \cdot \left(status_{best}(t) - \vec{Y}_j(t)\right) - g_1 \cdot rand_1 \cdot \sum_{W=1}^{L}\left(\vec{Y}_W(0) - \vec{Y}_j(0)\right) \qquad (26)$$

Where $\overrightarrow{Y}_{j,best}(t)$ denotes the best status value obtained by individual j previously, and is defined by

$$\vec{Y}_{j,best}(t) = \arg min \left\{f\left(\vec{Y}_j(h)|1 \leq h \leq t\right)\right\} \qquad (27)$$

For $Manner_4$ is defined as

$$Manner_4 = g_3 \cdot rand\ _3 \cdot \left(\vec{Y}_{j,best}(t) - \vec{Y}_j(t)\right) - g_1 \cdot rand_1 \cdot \sum_{W=1}^{L}\left(\vec{Y}_W(0) - \vec{Y}_j(0)\right) \qquad (28)$$

Manner$_2$, Manner3 and Manner$_4$ refer to three dissimilar emotional cases. In the first case, one individual's movement is protective, aiming to preserve his achievements in Manner$_2$ due to the still mind. With the increased emotion, more rewards are expected, so in Manner$_3$, a temporized manner in which the dangerous avoidance is considered by individual to increase the society status. Furthermore, when the emotional is larger than one threshold, it simulates the individual is in surged mind, in this manner, he lost the some good capabilities, and will not listen to the views of others; Manner$_4$ is designed to simulate this phenomenon.

Communal Expressive (CE) Optimization Algorithm for reactive power problem

Stage a. Initialization of individuals arbitrarily in problem space.
Stage b. Compute the fitness value of each individual according to the objective function.
Stage c. For individual j, determining the value $\overrightarrow{Y_{j,best}}(0)$.
Stage d. For all population, determine the value $\overrightarrow{status_{best}}(0)$.
Stage e. Find out the emotional index according to Eq. (21-23) in which three emotion cases are determined for each individual.
Stage f. Find out the decision with Eq. (24-28), correspondingly.
Stage g. Engender mutation operation.
Stage h. If the criterion is fulfilled, output the finest solution; otherwise, go to stage c.

3. Results and Analysis

At first Communal Expressive (CE) Optimization Algorithm has been tested in standard IEEE 118-bus test system [26].The system has 54 generator buses, 64 load buses, 186 branches and 9 of them are with the tap setting transformers. The limits of voltage on generator buses are 0.95 -1.1 per-unit., and on load buses are 0.95 -1.05 per-unit. The limit of transformer rate is 0.9 -1.1, with the changes step of 0.025. The limitations of reactive power source are listed in Table 1, with the change in step of 0.01.

Table 1. Limitation of reactive power sources

BUS	5	34	37	44	45	46	48
QCMAX	0	14	0	10	10	10	15
QCMIN	-40	0	-25	0	0	0	0
BUS	74	79	82	83	105	107	110
QCMAX	12	20	20	10	20	6	6
QCMIN	0	0	0	0	0	0	0

The statistical comparison results of 50 trial runs have been list in Table 2 and the results clearly show the better performance of proposed Communal Expressive (CE) Optimization Algorithm.

Table 2. Comparison results

Active power loss (p.u)	**BBO [27]**	**ILSBBO/ strategy1 [27]**	**ILSBBO/ strategy1 [27]**	**Proposed CE**
Min	128.77	126.98	124.78	115.78
Max	132.64	137.34	132.39	119.28
Average	130.21	130.37	129.22	116.10

Then the Communal Expressive (CE) Optimization Algorithm has been tested in practical 191 test system and the following results have been obtained. In Practical 191 test bus system – Number of Generators = 20, Number of lines = 200, Number of buses = 191 Number of transmission lines = 55. Table 3 shows the optimal control values of practical 191 test system obtained by CE method. And table 4 shows the results about the value of the real power loss by obtained by Communal Expressive (CE) Optimization Algorithm.

Table 3. Optimal Control values of Practical 191 utility (Indian) system by CE method

VG1	1.10		VG 11	0.90
VG 2	0.74		VG 12	1.00
VG 3	1.01		VG 13	1.00
VG 4	1.01		VG 14	0.90
VG 5	1.10		VG 15	1.00
VG 6	1.10		VG 16	1.00
VG 7	1.10		VG 17	0.90
VG 8	1.01		VG 18	1.00

VG 9	1.10		VG 19	1.10
VG 10	1.01		VG 20	1.10

T1	1.00		T21	0.90		T41	0.90
T2	1.00		T22	0.90		T42	0.90
T3	1.00		T23	0.90		T43	0.91
T4	1.10		T24	0.90		T44	0.91
T5	1.00		T25	0.90		T45	0.91
T6	1.00		T26	1.00		T46	0.90
T7	1.00		T27	0.90		T47	0.91
T8	1.01		T28	0.90		T48	1.00
T9	1.00		T29	1.01		T49	0.90
T10	1.00		T30	0.90		T50	0.90
T11	0.90		T31	0.90		T51	0.90
T12	1.00		T32	0.90		T52	0.90
T13	1.01		T33	1.01		T53	1.00
T14	1.01		T34	0.90		T54	0.90
T15	1.01		T35	0.90		T55	0.90
T19	1.02		T39	0.90			
T20	1.01		T40	0.90			

Table 4. Optimum real power loss values obtained for practical 191 utility (Indian) system by CE method.

Real power Loss (MW)	**CE**
Min	143.028
Max	147.178
Average	144.110

4. Conclusion

Proposed Communal Expressive (CE) Optimization Algorithm has been successfully solved reactive power problem. This Communal Expressive (CE) Optimization Algorithm is applied to obtain the optimal control variables so as to minimize the real power loss the system. The proposed algorithm has been tested in standard IEEE 118 & practical 191 bus test systems. And the results were compared with other standard algorithms. Simulation study reveal about the best performance of the proposed algorithm in reducing the real power loss and voltage profiles are well within the limits.

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