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# Real Power Loss Reduction by Revolutionary Algorithm

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*Keywords: optimal reactive power, transmission loss, kidney search algorithm.*

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REALPOWERLOSSREDUCTIONBYREVOLUTIONARYALGORITHM

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# Real Power Loss Reduction by Revolutionary Algorithm

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## I. Introduction

Optimal reactive power problem is a multi-objective optimization problem that minimizes the real power loss and bus voltage deviation. Various mathematical techniques like the gradient method [1-2], Newton method [3] and linear programming [4-7] have been adopted to solve the optimal reactive power dispatch problem. Both the gradient and Newton methods have the complexity in managing inequality constraints. If linear programming is applied then the input- output function has to be uttered as a set of linear functions which mostly lead to loss of accuracy. The problem of voltage stability and collapse play a major role in power system planning and operation [8]. Global optimization has received extensive research awareness, and a great number of methods have been applied to solve this problem. Evolutionary algorithms such as genetic algorithm have been already proposed to solve the reactive power flow problem [9, 10]. Evolutionary algorithm is a heuristic approach used for minimization problems by utilizing nonlinear and non-differentiable continuous space functions. In [11], Genetic algorithm has been used to solve optimal reactive power flow problem. In [12], Hybrid differential evolution algorithm is proposed to improve the voltage stability index. In [13] Biogeography Based algorithm is projected to solve the reactive power dispatch problem. In [14], a fuzzy based method is used to solve the optimal reactive power scheduling method. In [15], an improved evolutionary programming is used to solve the optimal reactive power dispatch problem. In [16], the optimal reactive power flow problem is solved by integrating a genetic algorithm with a nonlinear interior point method. In [17], a pattern algorithm is used to solve ac-dc optimal reactive power flow model with the generator capability limits. In [18], F. Capitanescu proposes a two-step approach to evaluate Reactive power reserves with respect to operating constraints and voltage stability. In [19], a programming based approach is used to solve the optimal reactive power dispatch problem. In [20], A. Kargarian et al present a probabilistic algorithm for optimal reactive power provision in hybrid electricity markets with uncertain loads. Kidney search algorithm (KS) is a new evolutionary optimization algorithm that derives its functionality from the kidney process in the body of a human being, and was initially introduced by [21]. When using the KS algorithm, the solutions are rated based on the average value of the objective functions of the solutions in a particular populace in a particular round. Optimal solutions are identified in the filtered blood and the rest are considered as inferior solutions. This process simulates the process of filtration known as glomerular in the human kidney. The inferior solutions once again are considered during other reiterations, and if they don't satisfy the filtration rate after the application of a set of movement operators, they are ejected from the set of solutions. This also stimulates the reabsorption and secretion features of a kidney. Additionally, a solution termed as the optimal solution is expelled if it does not prove to be better than the solutions classified in the worst sets; this simulates the blood secretion process by the kidney. After placing each of the solutions in a set, the optimal solutions are ranked, and the filtered and waste blood is combined to form another population that is subjected to an updated filtration rate. Filtration offers the needed manipulation to generate a new solution and reabsorption provides further examination. This paper proposes Kidney Search (KS) algorithm to solve the optimal reactive power problem. Proposed KS algorithm has been evaluated in standard IEEE 30 bus test system and the simulation results show that the proposed approach outperforms all the entitled reported algorithms in minimization of real power loss.

## II. Problem Formulation

The optimal power flow problem is treated as a general minimization problem with constraints, and can be mathematically written in the following form:

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$$\text{Minimize } f(x, u) \tag{1}$$

subject to

$$g(x,u)=0 \tag{2}$$

and

$$h(x,u) \leq 0 \tag{3}$$

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:

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

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

$$u = \left(V_g, T, Q_c\right)^T \tag{5}$$

or

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

Where ng, nt and nc are the number of generators, number of tap transformers and the number of shunt compensators respectively.

## III. Objective Function

*a) Active power loss*

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

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

or

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

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.

*b) Voltage profile improvement*

For minimizing the voltage deviation in PQ buses, the objective function becomes:

$$F = PL + \omega_v \times VD \tag{9}$$

where $\omega_v$: is a weighting factor of voltage deviation.
VD is the voltage deviation given by:

$$VD = \sum_{i=1}^{Npq} |V_i - 1| \tag{10}$$

*c) Equality Constraint*

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

$$P_G = P_D + P_L \tag{11}$$

This equation is solved by running Newton Raphson load flow method, by calculating the active power of slack bus to determine active power loss.

*d) Inequality Constraints*

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

$$P_{gslack}^{min} \leq P_{gslack} \leq P_{gslack}^{max} \tag{12}$$

$$Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max}, i \in N_g \tag{13}$$

Upper and lower bounds on the bus voltage magnitudes:

$$V_i^{min} \leq V_i \leq V_i^{max}, i \in N \tag{14}$$

Upper and lower bounds on the transformers tap ratios:

$$T_i^{min} \leq T_i \leq T_i^{max}, i \in N_T \tag{15}$$

Upper and lower bounds on the compensators reactive powers:

$$Q_c^{min} \leq Q_c \leq Q_C^{max}, i \in N_C \tag{16}$$

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.

## IV. Kidney Search (KS) Algorithm

Kidney search (KS) algorithm is one of the population-based techniques of feature selection. As recommended by its name, it replicates various processes from the system of a biological kidney. Following are the four main elements of kidney procedures that are referenced during the imitation. 1. Filtration: movement of water and solutes from the blood to the tubules. 2. Reabsorption: transport of valuable solutes and water from the tubules to the blood. 3. Secretion: transfer of additional constituents that are destructive from the bloodstream to the tubule. 4. Excretion: moving waste products from the above processes through the urine. In KS initial phase [21], an arbitrary populace of potential solutions is formed while the objective function is computed for each of the solutions. In every iteration, there is a generation of other potential solutions through a movement toward the current optimal solution. Thus, through the application of filtration operator, there is a filtration of potential solutions with high intensity toward the filtered blood (FB) with others being transferred to waste (W). The reabsorption, secretion, and excretion methods of the

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human kidney procedure are replicated here during the search procedure to check various conditions entrenched to the algorithm. When a potential solution is transferred to W, there is an allowance by the algorithm to have a chance of improving a solution to get an opportunity of moving it into FB. When the chance is not well exploited, the solution is expelled from W, and a potential solution is moved into W. Conversely, when a potential solution is moved into FB after filtration and has a poor quality in comparison to the worst solution contained by FB, the solution is excreted. On the other hand, if the solution proves to be preferable compared to the worst, the worst solution contained in FB is secreted. Lastly, the different solutions contained in FB are ranked, and an update is done on the optimal solution and the filtration rate. FB and W, are later combined. Solutions in KS population represent solutes in a human kidney. For KS, there is a generation of a new solution through shifting of the solution from previous recapitulation process to the current optimal solution. The formula of the movement is as follows:

$$Z_{i+1} = Z_i + rand(Z_{best} - Z_i) \quad (17)$$

In Equation 17, Z denotes the solution in KS population comparable to a solute in a natural kidney. $Z_i$ is a solution involved in the it h iteration. Rand value is an arbitrary value between zero and another number while $Z_{best}$ is the current solution based on the preceding iterations. The equation can produce a good diversity of solutions based on a current and optimal solution. Moreover, relocating the solutions to the optimal solution strengthens the local conjunction competence of an algorithm.

Filtering of the solutions is done with a filtration rate computed using a filtration function during iterations. Calculation of the filtration rate ($l_r$) is done using the following formula:

$$l_r = \beta \times \frac{\sum_{i=1}^{s} f(y_i)}{s} \quad (18)$$

$\beta$ is a constant value between 0 and 1 and is attuned in advance. s represents the size of the population. $f(y_i)$ represents an objective function of solution y at ith iteration. It is evident in the above formula that the filtration rate, $l_r$ for iterations depends on the objective function value of solutions in that population. The equation represents a ratio of each solution determined by $\beta$ . When $\beta$ equals to zero, $l_r$ will equal to zero, meaning that the process of filtration for that algorithm will not take place. When the value of $\beta$ is set at 1, the average value for objective functions equals to the value of $l_r$. There are different rates of filtration to help in the merging of the algorithm. During iterations, objective function values get closer to the global optimal solution and the filtration rate is thus computed using the solutions. This provides the algorithm with improved solutions with exaggerated exploration procedure. Reabsorption operator can be defined as the process of giving a solution which is being moved to W and a chance to be included in FB. Any solution that is moved into W can be allocated to FB if after the operator accountable for the movement & (Eq.17) is applied. It meets the rates of filtration and qualifies to be allotted into FB. Ideally, this mimics the reabsorption process of solutes in the kidney of a human being. In exploration, reabsorption is important one. A secretion is a form of operator for those solutions which have been progressed to FB. When a solution that has the opportunity to be moved to FB but does not prove to be improved in comparison to FB worst solution, secretion takes place, and the solution is moved to W; else the solution vestiges in FB while the worst solution assigned in FB is excreted and moved into W. Secretion of solutions into W takes place if the solutions fail to satisfy the filtration rate after several attempts to be reabsorbed as part of FB. In such a case, the solution in W is replaced with any other solution. Implanting arbitrary solutions emulates the continuous process of inserting water and solutes into the glomerular capillaries of the kidney.

Fix the population
Estimate the solution in the population
Fix the best solution $Z_{best}$ ,
Fix filtration rate, $l_r$, by equation (18)
Fix waste, W
Fix filtered blood, FB
Fix number of iteration,
Do while (iteration < $number\ of\ iterations$)
For all $Z_i$
Calculate new $Z_i$ by equation (17)
Check $Z_i$ using $l_r$
If $Z_i$ allocated to W,
Put on reabsorption and engender $Z_{new}$ by using equation (17)
If reabsorption is not satisfied ($Z_{new}$ cannot be part of FB)
Eliminate $Z_i$ from W (excretion)
Put on an arbitrary Z into W to swap $Z_i$
End if
$Z_i$ is reabsorbed
Else
If it is better than the $Z_{worst}$ $in\ FB$
$Z_{worst}$ is secreted
End if
End if
End for
Rank the $Z_s$ from FB and modernize the $Z_{best}$
Amalgamate W and FB
Modernize filtration rate $l_r$ by equation (18)
End while
Return $Z_{best}$



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## V. Simulation Results

Validity of the proposed Kidney Search (KS) algorithm has been verified by testing in IEEE 30-bus, 41 branch system and it has 6 generator-bus voltage magnitudes, 4 transformer-tap settings, and 2 bus shunt reactive compensators. Bus 1 is taken as slack bus and 2, 5, 8, 11 and 13 are considered as PV generator buses and others are PQ load buses. Control variables limits are given in Table 1.

*Table 1:* Primary Variable Limits (Pu)

| Variables | Min. | Max. | category |
|---|---|---|---|
| Generator Bus | 0.95 | 1.1 | Continuous |
| Load Bus | 0.95 | 1.05 | Continuous |
| Transformer-Tap | 0.9 | 1.1 | Discrete |
| Shunt Reactive Compensator | -0.11 | 0.31 | Discrete |

In Table 2 the power limits of generators buses are listed.

*Table 2:* Generators Power Limits

| Bus | Pg | Pgmin | Pgmax | Qgmin | Qmax |
|---|---|---|---|---|---|
| 1 | 96.00 | 49 | 200 | 0 | 10 |
| 2 | 79.00 | 18 | 79 | -40 | 50 |
| 5 | 49.00 | 14 | 49 | -40 | 40 |
| 8 | 21.00 | 11 | 31 | -10 | 40 |
| 11 | 21.00 | 11 | 28 | -6 | 24 |
| 13 | 21.00 | 11 | 39 | -6 | 24 |

Table 3 shows the proposed Kidney Search (KS) algorithm successfully kept the control variables within limits.Table 4 narrates about the performance of the proposed Kidney Search (KS) algorithm. Fig 1 shows about the voltage deviations during the iterations and Table 5 list out the overall comparison of the results of optimal solution obtained by various methods.

*Table 3:* After optimization values of control variables

| Control Variables | KS |
|---|---|
| V1 | 1.0401 |
| V2 | 1.0405 |
| V5 | 1.0198 |
| V8 | 1.0289 |
| V11 | 1.0697 |
| V13 | 1.0499 |
| T4,12 | 0.00 |
| T6,9 | 0.01 |
| T6,10 | 0.90 |
| T28,27 | 0.91 |
| Q10 | 0.10 |
| Q24 | 0.10 |
| Real power loss | 4.2732 |
| Voltage deviation | 0.9082 |

*Table 4:* Performance of KS algorithm

| | |
|---|---|
| Iterations | 32 |
| Time taken (secs) | 9.92 |
| Real power loss | 4.2732 |

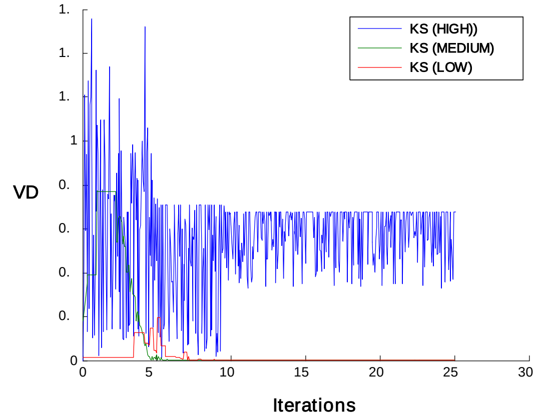


*Fig. 1:* Voltage deviation (VD) characteristics

*Table 5:* Comparison of results

| Techniques | Real power loss (MW) |
|---|---|
| SGA(Wu et al., 1998) [22] | 4.98 |
| PSO(Zhao et al., 2005) [23] | 4.9262 |
| LP(Mahadevan et al., 2010) [24] | 5.988 |
| EP(Mahadevan et al., 2010) [24] | 4.963 |
| CGA(Mahadevan et al., 2010) [24] | 4.980 |
| AGA(Mahadevan et al., 2010) [24] | 4.926 |
| CLPSO(Mahadevan et al., 2010) [24] | 4.7208 |
| HSA (Khazali et al., 2011) [25] | 4.7624 |
| BB-BC (Sakthivel et al., 2013) [26] | 4.690 |
| MCS(Tejaswini sharma et al.,2016) [27] | 4.87231 |
| Proposed KS | 4.2732 |

## VI. Conclusion

Kidney Search (KS) algorithm has been successfully applied for solving reactive power problem. In the proposed Kidney Search (KS) algorithm solutions are rated based on the average value of the objective function of the solutions in a particular population in a particular round. Proposed Kidney Search (KS) algorithm has been tested in standard IEEE 30 bus system and simulation results reveal about the improved performance of the proposed Kidney Search (KS) algorithm in plummeting the real power loss when compared to other stated standard algorithms.

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