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# Study of genetic algorithm performance through design of multi-step LC compensator for time-varying nonlinear loads

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ABSTRACT

Genetic algorithm (GA) is a search mechanism simulating the natural selection and population genetics. The performance of GA is related to processing time and the number of generations required for convergence and the convergence itself. This article studies how the performance of GA is affected by choosing its parameters and implementation techniques through designing the multi-step LC based on performance criteria; maximizing the power factor (*PF*), minimizing the transmission loss (*TL*), or minimizing the voltage total harmonic distortion (*VTHD*). The multi-step LC compensator consists of switchable units thus assuming that a single unit is not sufficient to ensure satisfactory results. GA is used to estimate that steps while holding the performance quantities at the corresponding desired values and constraining the compensator values which would create resonance. The contribution of the proposed procedure is demonstrated in examples taken from previous publications. Finally, simulated results show the performance of GA is widely affected by choosing its parameters and implementation techniques and hence it could be improved.



## 1. Introduction

Distortion in electric power systems takes place as a direct result of the non-linear nature of electric systems thus all of source, network and load cause the terminal voltage and supply current to be distorted causing harmful effects on the power system [1–4]. LC compensator is the best choice for large networks since the inductive part limits the current at high frequencies resulting in low cost and rating [5]. For non-linear loads, the LC compensator provides both of reactive compensation and harmonics filtering resulting in higher *PF* and lower distortion [6].

Besides the problem of harmonic distortion itself, the time-varying nature of harmonics and the system parameters, equivalent load and network equivalent impedances, [7,8] comes to have a considerable impact on the compensator design. Passive compensator sometimes fails to implement its function when the harmonic characteristics widely change. In this case, the active filter is introduced since the active filter eliminates harmonics completely. Use of active filters provides the following; no resonance, no distortion and unity*PF*. The main problem of the active power filter is the high cost relatively compared to the passive type [9]. However, multi-step compensator comes to be the final trial before suggesting an active filter to be installed. This trial fails when the number of switchable units increases such that the use of the multi-step compensator is not economic since the cost of the switchable type capacitors increases with the number of units for the same VA rating. [10] shows how the probabilistic analysis can provide guidance for the design of multi-step passive compensator, consisting of either filters or capacitors.

The proposed algorithm attempts to optimize the multi-step LC compensator by converting the main PDF with high variance into minor $PDF_s$ with lower variances resulting in improved expectation of the optimization quantity according to the scheduled number of the compensator steps. The steps of the multi-step LC compensator are selected such that compensator fulfills one of the following basic objective criteria; maximizing*PF*, minimizing*TL* or minimizing*VTHD*. In contrast to the C-part; the L-part has the advantage of step-less control thus, the optimized steps are restricted only for the C-part.

GA is used to estimate the desired compensatory steps to achieve the specified optimization criterion. GA provides many advantages over the direct techniques that it gives a group of solutions, not a single one [11]. GA is traveling in a search space using more individuals so that they are less likely to get stuck in a local extreme like the other methods as shown in Fig. 1 where the grading in darkness resembles fitness of solutions. Also, when many

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**Nomenclature**

| | |
|---|---|
| $CTHD$ | Current total harmonic distortion; % |
| $C$ | Compensator capacitance; F |
| $I_C$ | RMS capacitor current; a |
| $I_{Ck}$ | RMS capacitor current at harmonic order k; a |
| $I_{Lk}$ | Load current at harmonic order k; a |
| $I_S$ | Supply current; a |
| $I_{Sk}$ | Supply current at harmonic order k; a |
| $L$ | Lower value of the compensator C part; F |
| $P_L$ | Load active power; KW |
| $P(X)$ | Probability-distribution function for discrete random variables; % |
| $S_L$ | Load complex power; KVA |
| $r$ | Uniformly distributed random variable; % |
| $U$ | Upper value of the compensator C part; F |
| $VTHD$ | Voltage total harmonic distortion; % |
| $V_S$ | Supply voltage; V |
| $V_{Sk}$ | Supply voltage at harmonic order k; V |
| $V_L$ | Terminal voltage; V |
| $V_{Lk}$ | Terminal voltage at harmonic order k; V |
| $X_C$ | Compensator capacitive reactance at the nominal frequency; Ohm |
| $X_L$ | Compensator inductive reactance at the nominal frequency; Ohm |
| $Z_{Ck}$ | Compensator impedance at harmonic order k; Ohm |
| $Z_{Lk}$ | Load impedance at harmonic order k; Ohm |
| $Z_T$ | Source and transmission impedance at harmonic order k; Ohm |

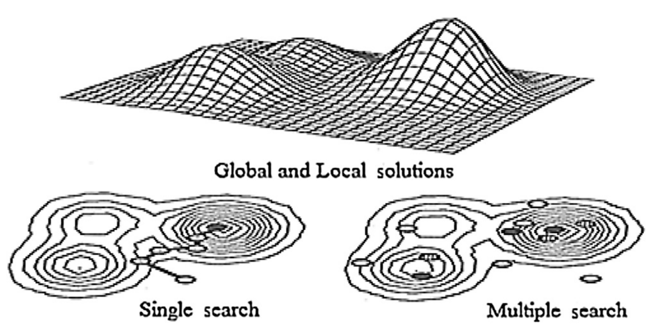


**Fig. 1.** Nature of optimization process using GA.

solutions are available not a single one, more objective functions could be tested. Finally, GA uses only the values of the objective function. The derivatives are not used in the search procedure [12].

The biological mechanism of GA could be illustrated using the chart shown in Fig. 2. It is a simulation of the mechanism of GA. Each chromosome consists of two genes with two states; black and white. Chromosomes having the description (F) are fit and they are able to be parents for a new generation. The fit chromosomes have resulted from genetic combinations having at least a black gene however others result in the description (N). The chromosome having the description (N) is not fit and has a weak chance to be a parent for the next generation. With time, the most chromosomes will be fit and the chromosomes with the description (N) tend to disappear from the population. Fig. 3 shows the flowchart corresponding to the previous mechanism. It summarizes the main parts of GA [13].

The GA parameters and implementation techniques have great influence on the GA performance [14]. [14] Emphases that a good selection of the GA parameters improves both computation time and solution accuracy. It studies the influence of the population size of GA on the GA performance. The use of smaller populations results

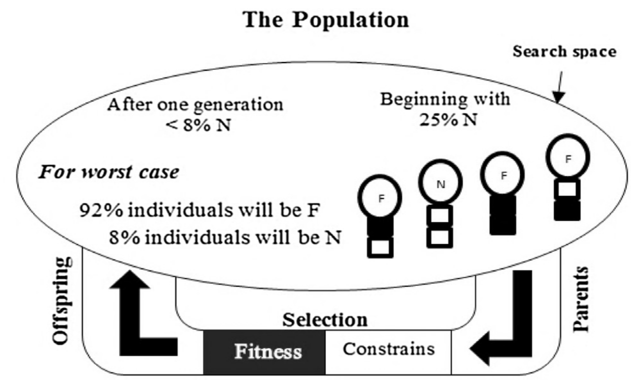


**Fig. 2.** Biological mechanism of GA.

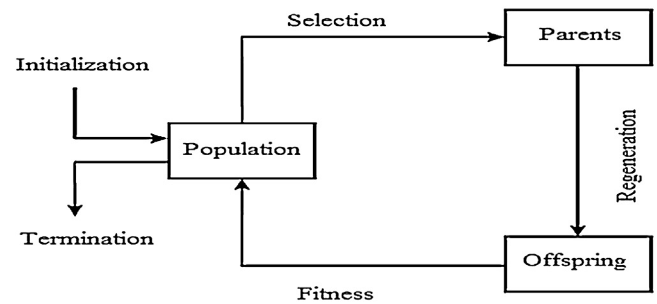


**Fig. 3.** Flowchart of biological mechanism of GA.

in a lower accuracy of the solution and smaller computational time. The further increase of the population size increases the accuracy of a solution to a certain limit at which the use of larger populations does not improve the solution accuracy and only increase the computation time. In [15] GA is developed for solving 0–1 knapsack problems (KPs) and performance of the GA is optimized using Taguchi method (TM). In addition to population size, crossover rate, and mutation rate, three types of crossover operators and three types of reproduction operators are taken into account for solving different 0–1 KPs, each has differently configured in terms of the size of the problem and the correlation among weights and profits of items. Three sizes and three types of instances are generated for 0–1 KPs and optimal values of the genetic operators for different types of instances are investigated by using TM. The optimum value of 50 is obtained for the population size regardless of the structures of the problems concerned. The mutation rate is decreased as the size of the problem increased. The double point crossover operator is not significant for the 0–1 KPs generated with respect to items and correlation among weights and profits of items. On the other hand, the appropriate crossover operator is obtained as a uniform for small size problems, while single point crossover operator for large size problems despite the correlation. The optimum parameters of GA designed for solving 0–1 KPs are dependent on the structure of the problem. Hence, the initial values of the parameters may be selected using the results of this study as a table look-up.

[16] Proposes a new chemical reaction optimization with greedy strategy algorithm (CROG) to solve KPs. The method encodes solutions as molecules and mimics the interactions of molecules in chemical reactions to search the optimal solutions. The experimental results have proven the superior performance of CROG compared to GA. However in [17], the CRO scheme is used to formulate the scheduling of Directed Acyclic Graph (DAG) jobs in heterogeneous computing systems. A Double Molecular Structure-based Chemical Reaction Optimization (DMSCRO) method is developed. The experimental results show that the pro-