# Single and multi-objectifs optimization with genetic algorithms of an insulator hood and stalk

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**Abstract**: The purpose of this article is to combine a numerical model in 2 dimensions to calculate the diametric surface and the electric field distribution on the insulating skirt of an insulator hood and stalk, with a mono and multi-objectifs optimizations methods using genetic algorithms. First, optimization of the electric field value on the stalk and the diametric surface separately (mono objective) is occured and in the second place, both objectives (multi-objectives) are combinated. The required constraints are: fixed both the leakage length and the diameter of the insulator.

## 1 INTRODUCTION

The optimizations methods are indispensable tools for the conception. An inventor's objective being to achieve a product that would present high performances with an optimal shape of the object that would drive to a cost of comes back minimal. The research grants a primordial importance in this domain [1].

The research succeeded to several methods of optimization, used in different domains according to the nature of the problem to optimize.

The conception of a disc insulator, that remains an element very used in the networks of transportation in high tension, must satisfy to the optimization of constraints of various natures. In the following work electric field and diametrical surface constraints will be exanimate.

The objective is to combine a finite elements method of electric field calculating and a numeric area computing with genetic algorithms optimizations methods (mono and multi objectives). to arrive to a insulator shape of that presents an electric field value reduced on the stem (reduction of the risk of flashover), as well as a reduction of the diametrical surface and finally to a compromise between these two criteria.

A modelling of the geometric disc insulator shape is necessary to study the distribution of the electric field on its insulating skirt and to calculate the diametrical surface. It is possible with using FEMM [2,3] software integrated in MATLAB for a better exploitation of the results gotten and permits to call then on the genetic algorithms.

Optimization multi objectives by NSGA II will allow us to succeed to a compromise between optimum of the value of the field and optimum of the value of the diametrical surface presented as a front of Pareto.

## 2 MODELLING OF THE INSULATING SKIRT

The studied system (figure.1) is an industrial disc insulator of type F12AS composed of a hood in casting joined to the earth, of a stem made of steel submitted to the high tension, and an insulating skirt in glass.

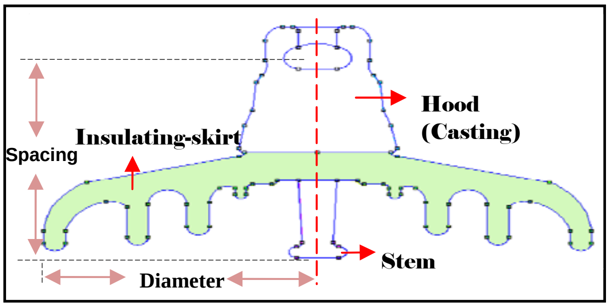


**Figure 1:** Model of simulation (Insulator F12AS)

Reproducing this insulating skirt needs to decompose its leakage distance in small segments identified by their length and the horizontal slope, and portions of circle defined by their radius and angle (figure.2).

The electric field distribution is determinate by considering the following assumptions:

- The shape system being circular and symmetrical, the model is examined on a bi dimensional plan representing a diametrical cut.
- The study is carried on the insulating skirt, all phenomenon that can be led by the materials used inside the hood are neglected.
- Neglect the discharge effect.

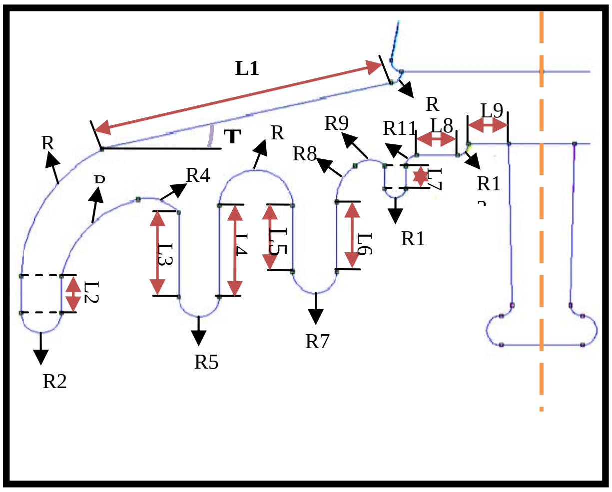


**Figure 2:** Reproduction of the insulator F12AS

As definite in the bibliographic studies [4-6], a single-lens optimization has for goal to look for the optimum of the function, propertied only one objective to improve.

The present work is to optimize the dimension of the F12AS insulator for two distinct objectives:

- An optimization of the maximal value of the electric field on the insulating surface of the industrial model.
- An optimization of the diametrical surface of the insulator.

In a previous work [7], we noted that whatever are the modifications brought to the shape of the insulating skirt, the electric field remained always maximal in the stem, and in the case of a flashover, the stem electrode is the most vulnerable zone. To optimize the electric field on the insulating skirt, we adopt like objective, the minimization of the electric field in the stem, with as variables the L2, L3, L4, L5, L6 and L7 lengths (figure 2).

The values of these variables must obey to equalities and inequalities constraints.

For the constraints of inequalities; every variable is consisted in one interval of variation that it must not exceed the "spacing" of the insulator.

Constraints of equalities; the insulator leakage distance is decomposed in two parts, a constant part equals to 317.7 mm and the other variable composed of the L2, L3, L4, L5, L6 and L7 lengths whose sum must not pass 103.3 mm to keep a leakage line constant of 421 mm. The diameter of the insulator is maintained constant all along the procedure of optimization.

These constraints can be summarized like follows:

Inequalities Constraints

$$\begin{cases} 1\,\mathrm{mm} \leq L2 \leq 10\,\mathrm{mm} \\ 1\,\mathrm{mm} \leq L3 \leq 30\,\mathrm{mm} \\ 1\,\mathrm{mm} \leq L5 \leq 20\,\mathrm{mm} \\ 1\mathrm{mm} \leq L7 \leq 26\,\mathrm{mm} \end{cases} \quad (1)$$

Equalities Constraints

$$\begin{cases} 2*L2 + 2*L3 + 2*L5 + 2*L7 = 100.3\,\mathrm{mm} \\ L4 = L3 + 2 \\ L6 = L5 + 1 \end{cases} \quad (2)$$

After a good definition of the optimization problem on the Toolbox, the research of the minimal electric field value is started.

After choosing the population size and the number of iterations, the algorithm generates a randomness initial population, from where it selects the half of the individuals having the best fitness values (the lower electric field on stem) as parents, then the selection and crossing operators intervene to create other individuals (children) from the parents to create the new population. This process repeats itself as far as reaching the number of iterations chosen.

Several results are gotten, each one different from the other according to the size of the initial population and the number of chosen generation.

For the single-lens optimization of the diametrical surface, the same stapes which are adopted in the case the electric field minimization are used, mean the L2, L3, L4, L5, L6 and L7 lengths are taken also like optimization variables. The leakage line length as well as the diameter of the insulator is maintained constant all along the procedure of optimization.

The multi-objectives optimization [8-18], that has for goal to find an interesting compromise between two objectives that wishes to improve, don't give only one optimal solution but a set of points (definite by the front of Pareto) that are optimal. The choice comes back to the inventor to opt for such or such solution.

The multi-objective survey has for objective to combine an optimization of the electric field value with the insulator diametrical surface optimization using the NSGAII algorithm.

As in the single-lens case, the optimization variables are the L2, L3, L4, L5, L6 and L7 lengths, the leakage distance as well as the diameter are kept also constant.

## 3 RESULTS

In this paper, the tension is considered constant tension of 30 kV that represents a value for which discharges can exist but the flashover doesn't take place yet.

The electric field amplitude distribution along the leakage distance is exanimate. A particular attention will be granted to the insulating skirt surface.

Reproduction of the industrial model shape is gotten in the figure 3 that also represents equal potential lines. The leakage distance length is of 421 mm and the insulating skirt surface is of 0,0073 $m^2$.

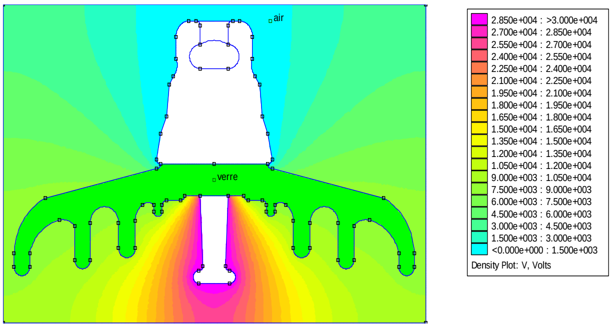


**Figure 3:** Drawn of the equal potentials on the industrial mode

Note from figure 4 that there are three points where the field is relatively raised; in the hood with a value of $10^6$ V/m, in the point corresponding to a flight length of 408 mm with a field value of $1{,}71.10^6$ V/m, then it decreases until $0{,}74.10^6$ V/m in 410 mm to increase fast as far as reaching the maximal value in the stem that is of $4{,}8.10^6$ V/m.

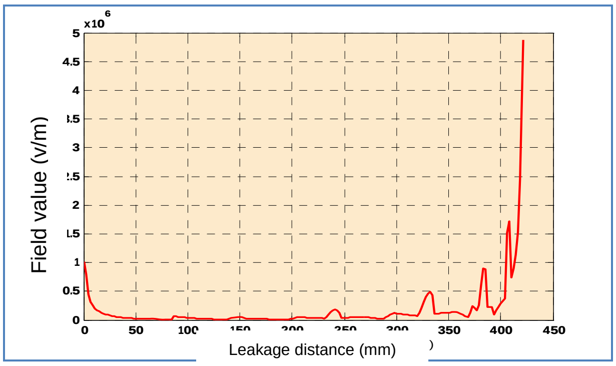


**Figure 4:** Distribution of the electric field amplitude on leakage distance while leaving from the hood (industrial model).

For mono objective optimization of the electric field value in the stem, a population of 100 individuals is taken, and the number of generations is of 100, in order to assure the convergence of the algorithm toward the global solution of the problem.

The table 1 summarizes the different changes done on the industrial model, the value of the field, the leakage distance and the optimized insulator surface.

**Table 1:** Comparison between the industrial and the optimized models

| | Industriel Model | Optimized Model |
|---|---|---|
| L2 (mm) | 8.5 | 1.865 |
| L3 (mm) | 21.5 | 1.084 |
| L4 (mm) | 23.5 | 3.084 |
| L5 (mm) | 16 | 23,062 |
| L6 (mm) | 17 | 24,062 |
| L7 (mm) | 4.1425 | 24.14 |
| Leakage distance (mm) | 421 | 421 |
| Field value (V/m) | 4.8690e+006 | 3.4948e+006 |
| Surface ($m^2$) | 0.0073 | 0.0071 |

The figure 5 represents the shape as well as the tracing of the equal potentials on the optimized model.

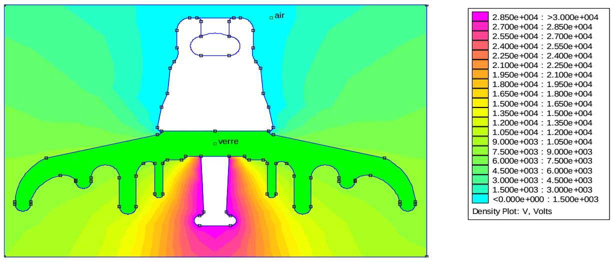


**Figure 5:** The optimized model shape

The value of the field decreases to $3{,}4948.10^6$ (-29%) in this result (figure 6).

An improvement of the diametrical surface is also noticed in this model with a reduction from 0.0073 ($m^2$) to 0.0071 ($m^2$) (-2.7%) (table 1).

Of the figure 7 giving the evolution of the fitness function toward the best value along the generations. Note that the algorithm keeps the same value of the fitness function ($3.4948.10^6$ V/m) from the 27th generation, what means that the convergence toward the optimum (minimum) global, that is of ($3{,}4948.10^6$ V/ms), begin from the 27th generation. The values of the variables correspondents to the best individual, who achieves this global optimum, are given in the figure 8.

The figure 9 giving the middle distance between the individuals along the generations shows the manner of which the individuals come closer between them. This distance decreases more and more, with the increase of the number of iterations, to nullify by reaching the point optimal from the 27th generation (proof of the algorithm convergence).

The figure 10 schematizing the best, worst and the mean fitness values along the generations, confirms that the algorithm converges toward the value ($3{,}4948.10^6$ V/m).

A particular attention will be granted to the disc insulator skirt surface when examining the electric field amplitude distribution along the leakage distance.

Reproduction of the industrial model shape is gotten in the figure 3 that also represents equal potential lines. The leakage distance is of 421 mm and the insulating skirt surface is of 0,0073 m. From the 27th generation, since it remains constant from this point.

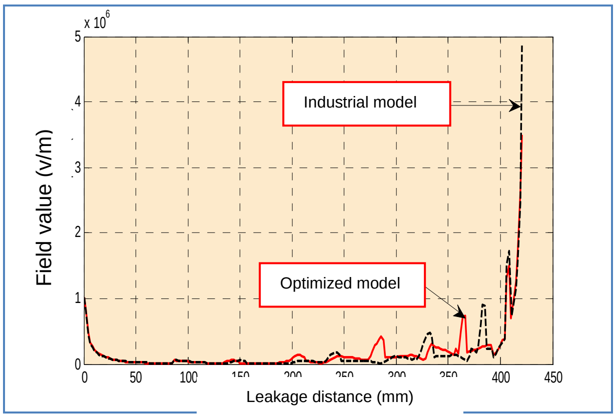


**Figure 6:** Shape of the model optimized

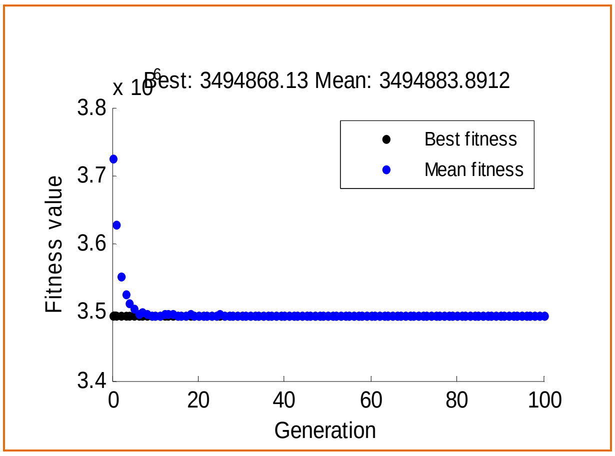


**Figure 7:** The evolution of the fitness function toward the best fitness value along the generations

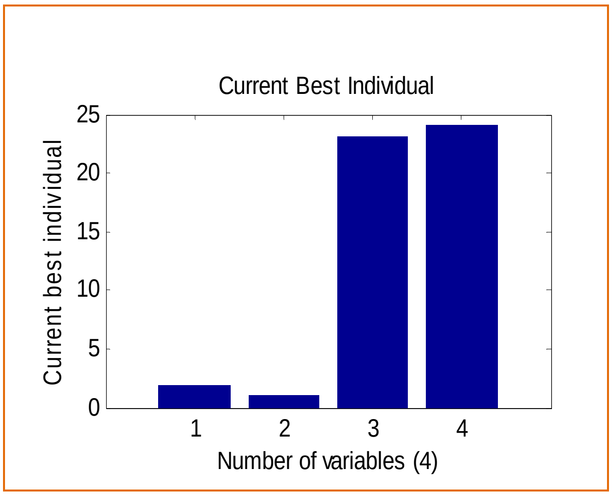


**Figure 8:** The values of the variables of the best individual gotten at the end of optimization.

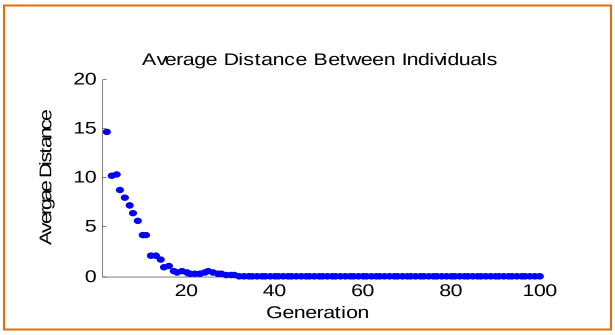


**Figure 9:** Middle distance between individuals along the generations.

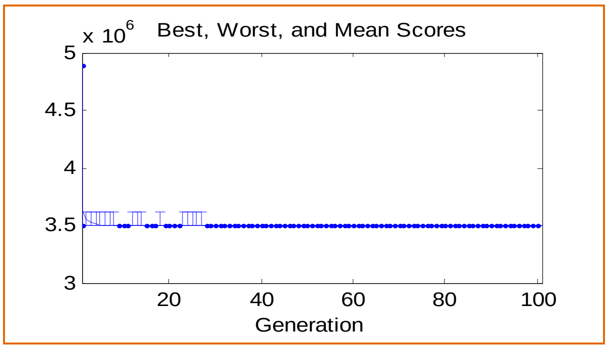


**Figure 10:** The best, worst and mean fitness values along the generations

For singleness objective optimization of the diametrical surface, the execution of the algorithm is thrown in the Toolbox GA, the number of generations chosen is 100 iterations to ascertain the algorithm convergence.

According to the figure 11 giving the best, worst and mean fitness values along the generations, it can note that the convergence begins since the 17th generation toward the 0.007m$^2$ value (-4%).

The figures 12 and 13 giving respectively, the evolution of the fitness function toward the best fitness value and the middle distance between individuals along the generations, confirm this last observation.

The variables of the best individual representing the optimum of surface are presented in the figure 14.

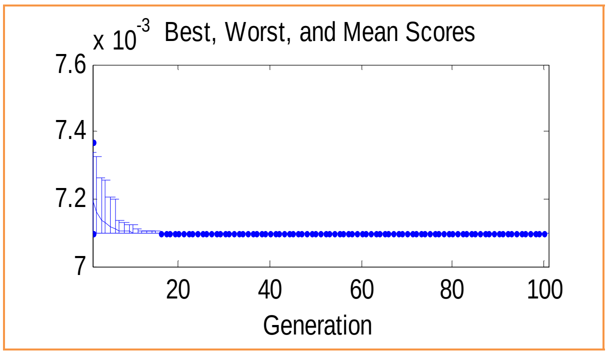


**Figure 11:** The best, worst and mean fitness values along the generations

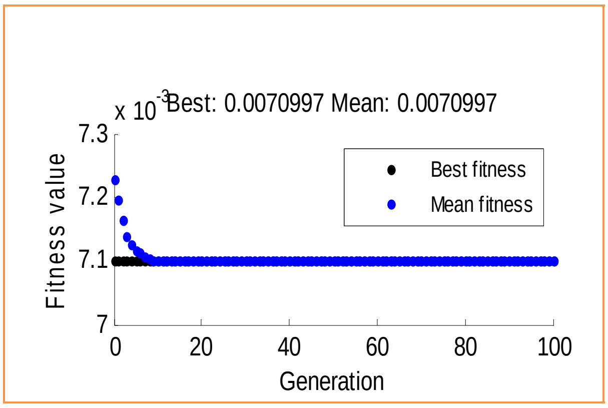


**Figure 12:** The evolution of the fitness function toward the best fitness value along the generations.

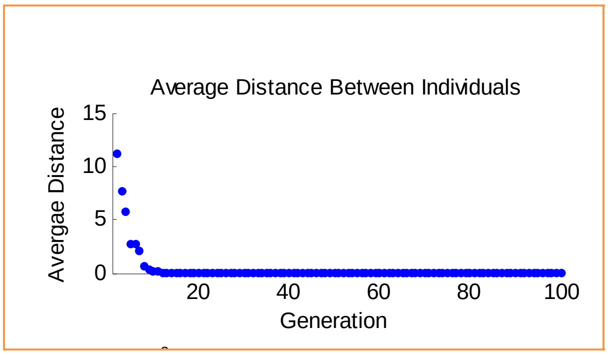


**Figure 13:** Middle Distance between individuals along the generations.

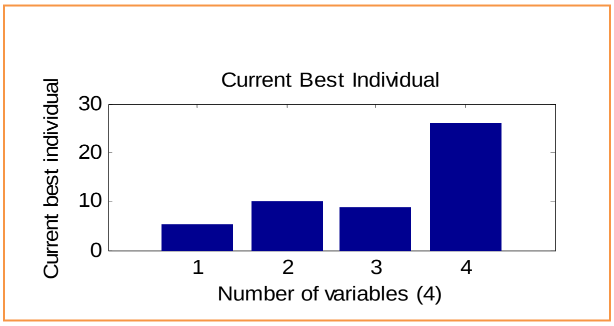


**Figure 14:** The values of the variables of the best individual gotten at the end of optimization.

Note from figures 8 and 14 giving the values of the variables of the best individual gotten at the end of optimization for the electric field and for the surface respectively, that these best individuals are different. In order to evaluate the compromise between the two objectives, we achieve a multi-objectives optimization.

The multi objectives Optimization have been started for 200 iterations and a population of 100 individuals, the gotten result is a front of Pareto that includes all optimal solutions given in the figure 15.

The rate of this forehead is a little deformed by the fact that the resolution is not obvious in multi objectives seen the difficulty of the problem and constraints imposed (leakage distance and constant diameter).

Note also that the values gotten in the single-lens optimization of the electric field and the diametrical surface are present in this front of Pareto.

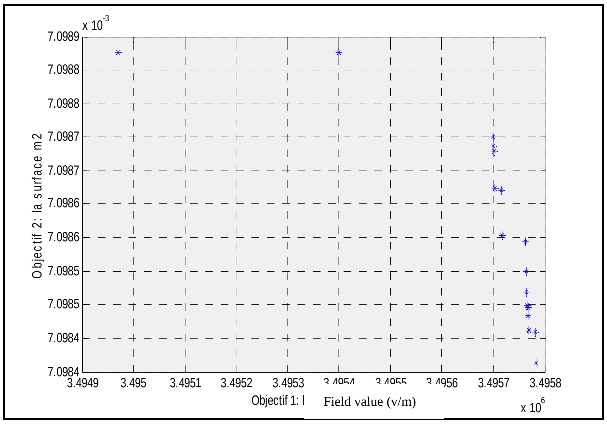


**Figure 15:** Front of Pareto for the multi-objective optimization (field and surface)

## 4 CONCLUSION

The study done witch objectif is to combine a numeric method of calculation of the electric field with optimization procedures by genetic algorithms (mono and multi objectives) showed the efficiency of these methods, while succeeding in optimizing the measurements of the disc insulator (F12AS) in relation to two objectives; the reduction of the electric field value in the stem as well as the diametrical surface.

For an optimization mono objective, the algorithm converges in the $27^{th}$ iteration for the electric field and the $17^{th}$ iteration for the diametrical surface.

The use of the NSGAII algorithm for the multi-objectives optimization allowed to have the optimal solutions as a Pareto forehead that gives the best possible compromises between two objectives (electric field and diametrical surface) where the choice of the appropriate solution comes back to the inventor.

The results gotten by single-lens optimization agree with the limits of the front of Pareto gotten by the multi-objectives optimization.

## 5 REFERENCES

[1] D. Boudieb « Application des algorithmes évolutionnaires en optimisation géométrique de forme » Thèse de magister en Génie mécanique Université M'Hamed Bouguera Boumerdès 10.06. 2008.

[2] G. Touzot, G. Dhatt, « Une présentation de la méthode des éléments finis », MALOINE S.A.éditeur, 543p, Paris 1981.

[3] D.Meeker, « finit element method magnetic » version 4.0, dmeeker@IEEE.org

[4] Genetic Algorithm and Direct Search Toolbox For Use with MATLAB® User's Guide Version 1.

[5] S. Amédée, Radet, Francois-Gérard « Algorithme génétiques » travail de fin d'études année 21.06. 2004.

[6] D.E.Goldberg « Genetic algorithms for search, optimization, and machine learning». Reading, MA: Addison-Wesley, 1989.

[7] D. Doufene, S. Bouazabia « Développement d'un modèle numérique d'isolateur pour l'étude de la répartition du champ électrique sur sa jupe isolante», 8th CNHT, Tiaret 9-11 mai 2011, Algérie.

[8] A. Zinflou « Système interactif d'aide à la décision basé sur des algorithmes génétiques pour l'optimisation multi-objectifs », Exigence partielle de la Maitrise en informatique,Université de Québec à Chicoutimi. 29 juin 2004.

[9] Y. Colette, P. Siarry, « Optimisation multiobjectif », Edition Eyrolles, 2002.

[10] E. Zitzler, « Evolutionary Algorithms for Multiobiective Optimization». EUROGEN 2001 - Evolutionary Methods for Design, Optimisation and Control with Applications to industrial Problems.

[11] V. Pareto. « Cours d'économie politique ». Lausanne, F. Rouge. (1896).

[12] E. Zitzler, « Evolutionary Algorithms for Multiobjective Optimization»: Methods and Applications", PhD thesis, Swiss Federal Institute of Technology (ETH), Zurich, Switzerland, 1999.

[13] N. Srinivas, Kalyanmoy Deb. « Multiobjective Optimization Using Nondominated Sortingin Genetic Algorithms». Evolutionary Computation, 2(3):221 - 248, 1994.

[14] K. Deb, S. Agrawal, A. Pratap, T. Meyarivan. «A fast and elitist multiobjective genetic algorithm for multi-objective optimization: NSGA-II» In Proceedings of the Parallel Problem Solving from Nature VI (PPSN-VI), pages 849,858, 2000.

[15] K. Deb, A. Pratap, T. Meyarivan. «Constrained test problems for multi-objective evolutionary optimization» In Proceedings of Evolutionary Multi-Criterion Optimization, pages 284-298, 2001. Chichester, U.K.: Wiley, 2001.

[16] G. Khemaies «Méthodologie de conception système à base de plateformes reconfigurables et programmable », Thèse de Doctorat, Universite ParisXI. Mars 2005.

[17] K. Deb, A. Pratap, S Agarwal, T. Meyarivan. «A Fast and Elitist Multiobjective Genetic Algorithm: NSGA-II ». IEEE Transactions on Evolutionary Computation, Vol. 6, No 2, pp.182–197, (2002).

[18] L. Derdi, «Les algorithmes génétiques». Thèses de Doctorat. INRS-ETE, 2005.