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APPLICATION OF PROGRESSIVE QUADRATIC RESPONSE SURFACE METHOD FOR AN OSCILLATION PROBLEM OPTIMIZATION

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Abstract. The paper presents an effective optimization strategy applied in a physical structure optimization of a semiconductor Power MOSFET with expensive constraint computations. In order to deals with inaccuracy due to inevitable numerical errors in the objective function calculation (the power losses of the power MOSFET), the paper proposes to use the Progressive Quadratic Response Surface Method (PQRSM). The paper focuses on three aspects: the inevitable numerical errors in the power losses computation, the PQRSM principle, and finally the comparisons of several optimization methods on this problem.

Keywords: Genetic optimization algorithms, time step, Progressive Quadratic Response Surface Method, Power MOSFET, numerical error.

I. INTRODUCTION: OBJECTIVE FUNCTION

In our application, the computation of the objective function is based on a numerical method. The power losses of the power MOSFET within a period are calculated by adding the switching losses and conduction losses. The conduction losses are defined as in [5]. The switching losses are a sum of the losses at each switching on the operating period. So, a quasi static modelling is used, with complicated numerical-analytical expression, depending on a time step (*timestep*). The accuracy and the computation time of this numerical method are strongly sensible to this computation time step. The computation error creates oscillation on the objective function (see Figure 1). This numerical error also depends itself on the physical parameters

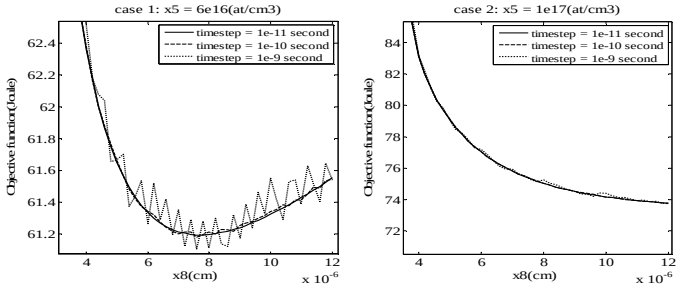

Figure 1. Objective function according to x_8 with 3 *timestep* values and two x_5 values in two cases

X=[x_1, x_2,…, x_9] (i.e. the time constants are influenced by X)(see cases 1 and 2 in Figure 1). Therefore, without modifying the objective function calculation method, this oscillation is inevitable in the design optimization where the physical parameters are continuously changed, at each optimization iteration and each objective function calculation. In the design optimization, the objective function oscillation may lead to spurious local optimum [4] when a gradient-based optimization algorithm is applied. So, a first solution is to implement an adaptative computation time step, but it is yet time consuming. By observing (Figure 1) that the average value of the computed objective function (i.e., by removing the oscillations), is its good value, the paper proposes to use an approach based on Response Surface Approximation (RSA).

II. PROGRESSIVE QUADRATIC RESPONSE SURFACE METHOD

RSA has become an important tool in the design optimization to deal with high computational costs, numerical noise problems and numerical inaccurate gradient evaluations [1][2]. In this optimization problem, PQRSM has been chosen from [3]. PQRSM requires less sampling points to build a quadratic approximate function than conventional RSA. The PQRSM principle is detailed in [1][2][3]. The objective and constraint functions are approximated by quadratic functions (Eqn. 1) within a fair design space.

(1) $$f = c_0 + \sum_{i=1}^{n} c_i.x_i + \sum_{i=1}^{n}\sum_{j=i}^{n} c_{ij}.x_i.x_j$$, where n is number of design variables; x_i and x_j are the design variable; c_0, c_i and c_{ij} are the unknown polynomial coefficients.

PQRSM sequentially optimizes the approximate optimization problem in the context of the trust region model management strategy [3]. In this way, a model is defined to reduce the trust region at each iteration, around the solution carried out by optimization. This strategy is reapplied until the optimization problem converges. The trust region model management in [3] is difficult to adapt with the multidisciplinary design optimization problem. In our case, this model management is simplified. Each dimension of the design space is simply reduced by two (see Figure 2). This design space management will be detailed in the full paper.

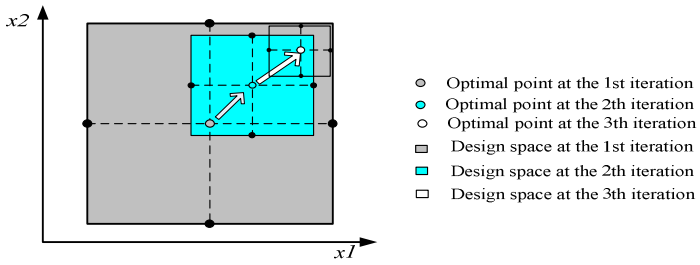

Figure 2. Principle of the design space management with three iterations

III. RESULTS AND DISCUSIONS

III.1 Optimization analysis

In order to show the PQRSM principle, an optimization with three iterations is presented in this section. The optimization problem has 9 unknown parameters as shown in the Table 1 and several constraints.

Table 1. Unknown parameters analysis

Parameters	initial design space	after 1st iteration	after 2nd iteration	after 3rd iteration
x_1. 1e-4	[20 : 100]	**100** [60 : 100]	**72.83** [60 : 80]	**67.04**
x_2. 1e-4	[20 : 200]	**127.85** [65 : 155]	**82.81** [65 : 110]	**67.04**
x_3	[300 : 3000]	**462** [300 : 1650]	**1650** [1312 : 1988]	**1988**
x_4. 1e19	[5 : 15]	**10.7** [7,5 : 12,5]	**9.8** [8.8 : 12.0]	**10.1**
x_5. 1e16	[6 : 20]	**10.1** [6 : 13]	**7.0** [6 : 9.5]	**6.7**
x_6. 1e-4	[0,5 : 1,4]	**1.04** [0,95 : 1,4]	**1.23** [1.07 : 1.29]	**1.18**
x_7. 1e-4	[6 : 8]	**6.92** [6,5 : 7,5]	**7.0** [6.75 : 7.25]	**6.87**
x_8. 1e-7	[30 : 120]	**82** [52 : 98]	**75** [63 : 87]	**63**
x_9. 1e-4	[5 : 15]	**10.98** [7,5 : 12,5]	**10.0** [8.75 : 11.25]	**8.75**
Residual Approximation		**328.187**	**0.0173**	**1.23e-5**
Objective Function		**29.33**	**11.88**	**11.09**

After three iterations of PQRSM, the objective function value decreased from 29.33 to 11.09. The approximation of objective function is bad in the initial design space, but it is accurate in the next iterations when the design space decreased. So, an optimum is carried out after few iterations.

III.2 Optimization Result

In this section, some results of our power MOSFET design are presented. PQRSM and a genetic algorithm (Evolution Strategy (ES) [6]) are compared (see Table 2). After several optimizations by ES algorithm, the best solution is carried out with 600 generations, 40 children and 6 parents, 24000 function evaluations; while PQRSM converges after 8 iterations, 1152 function evaluations.

Table 2. Optimization result with PQRSM and ES algorithm(ng generation, nc chidren, np parents)

Algorithm	x_1 .1e-4	x_2 .1e-4	x_3	x_4 .1e19	x_5 .1e16	x_6 .1e-4	x_7 .1e-4	x_8 .1e-7	x_9 .1e-4	Objective Function	Calculation time(minute)
PQRSM	52.86	52.7	2962	8.6	6.9	1.12	6.79	57	7.74	**10.08**	**4**
ES(ng=600,nc=40,np=6)	52.17	52.2	3000	5.2	6.48	0.97	6.00	53.5	5.55	**9.86**	**45**

In term of objective function value, the two algorithms give close results. But PQRSM is 11 times faster than ES algorithm. The parameter and sensibility analysis will be presented and discussed in the full paper.

VI. CONCLUSION

In the paper, the Progressive Quadratic Response Surface Method is presented and applied to reduce the oscillation problem in the power losses computation of Power MOSFET as it carries out the optimization. The optimization results of PQRSM has been compared with the ES algorithm, with similar results but faster computation.

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