To cite this version:
AN ITERATIVE METHOD FOR SELECTING DECISION VARIABLES IN ANALYTICAL OPTIMIZATION PROBLEMS

Houdhayfa Ounis, Xavier Roboam, Bruno Sareni

Université de Toulouse, LAPLACE, UMR CNRS-INPT-UPS, 2 rue Camichel, 31071 Toulouse, France
{ounis, roboam, sareni}@laplace.univ-tlse.fr

Abstract. In this paper, we present an iterative method to assist the designer in the setting of decision variables in an optimization problem with analytical models. This method is based on a Direct Structure Matrix (DSM) which allows a clear representation of interactions between variables. This approach is applied to the geometrical model of a High Speed Permanent Magnet Synchronous Machine (HSPMSM).

Keywords: DSM (Direct Structure Matrix), Decision variables, Optimization, Model structuring

INTRODUCTION

Till now, the choice of the decision variable vector in an optimization problem is done by experts and no method has been proposed to automatically perform this process. However, a poor choice of decision variables can easily penalize the search for an optimal solution (losing degrees of freedom), or increase the complexity of the optimization problem. In this paper, we propose an iterative method based on a Direct Structure Matrix (DSM) [1], [2] of the model for the choice of the decision variables. This method can take several criteria into account for selecting decision variables according to the need and interest of the designer.

DECISION VARIABLE SELECTION

To better understand the method, it is applied to the following simple model defined by equations (1)-(4):

\[ x_4 = 2x_1x_6 \]  \hspace{1cm} (1)
\[ x_5 = 2x_2 \]  \hspace{1cm} (2)
\[ x_6 = x_1 + 2x_4 \]  \hspace{1cm} (3)
\[ x_7 = x_3x_6 \]  \hspace{1cm} (4)

Fig. 1 shows the matrix representation of the model (non-oriented DSM), each variable being represented by a row and a column identically labeled and each cell representing the interaction between two variables and containing the equation numbers if couplings occur.

This model includes four equations and seven variables which imply a minimum number of decision variables equal to “3”. Choosing arbitrarily “[x_1, x_2, x_3]” as decision variables leads to a non-triangular oriented DSM (it can be seen from Fig. 2 that equations (1) and (3) are coupled). In our example, all equations are reversible and the model should be rewritten in order to remove this coupling. In the case of non-reversible equations, the choice of this decision variable vector is not relevant. The process of the proposed selection method of the decision variables is illustrated in Fig. 3. The starting point of this method is the non-oriented DSM for which all interactions between all variables in the model are shown. Selection criteria are imposed by the designer depending on the problem specificities (e.g. variable sensitivity with respect to the model outputs). In our case, we use the simplest version of the method by choosing the frequency occurrence of the variables (called index 1) in the model (see Table 1) and the number of coupled variables (called index 2) per equation (see Table 2). The following steps are followed:
The geometrical model of a High Speed Permanent Magnet Synchronous Machine is given in details in [3]. It includes “81” variables and “70” equations. “11” decision variables (current density “$J_d$”, number of pole pairs “$p$”, number of slots per pole per phase “$N_{op}$”, equivalent gap “$g$”, yoke induction “$B_y$”, radius length ratio “$R_{rl}$”, slot depth radius ratio “$R_{dr}$”, magnet filling coefficient “$K_p$”, slot filling coefficient “$K_i$”, rated speed “$N_{rp}$” and rated torque “$T_{hp}$”) have been initially imposed by expertise. Table 3 shows the comparison these variables and those given by our method (only differences are underlined here). In the original problem, the calculation of the bore radius “$r_b$” is done through simplifying assumptions because of coupling in the equations of the model (without these assumptions, an additional decision variable must be added for solving the problem). The application of our selection method has overcome this problem by selecting the radius “$r_b$” and “$l$” instead of “$R_{de}$” and “$R_{di}$” and confirms the choice of the expert for the remaining decision variables.

**REFERENCES**

