# **CHAPTER 4**

# **OPTIMIZATION AND DESIGN**

## Introduction

In the previous chapter, electrical and mechanical design parameters of the selected axial flux permanent magnet generator are expressed. To do that, mathematical design equations and related drawings are represented. These equations are important for this thesis work. Because they are used in the main design code, which is written in MATLAB. Also in the previous chapter, verification of the given analytical equations of the some important design parameters is given by means of finite element analysis for a sample design. For this purpose, comparison of the design equations and the finite element analysis is made in terms of airgap flux density and induced emf. It’s concluded that the results show good agreement. Therefore, these equations can be used in the optimization algorithm with high accuracy. In this chapter, optimization process of the given design will be summarized and optimum design parameters of the proposed 5 MW AFPM generator will be determined. First, evolutionary algorithms (EA) will be reviewed including the selected genetic algorithm (GA). Then, process of the genetic algorithm based optimization method, which is used in this thesis study, will be explained in detail. Optimization of the proposed generator is constructed with MATLAB optimization toolbox. Also in this chapter, a brief information of this toolbox and used parameters in the optimization algorithm will be covered. Finally, optimized design parameters of the proposed 5 MW 12 rpm AFPM generator will be given. These design parameters will be used for the finite element modelling and analysis in the following chapter.

## Evolutionary Algorithms (EA) and Genetic Algorithm (GA)

There exist different mathematical search algorithms and conventional methods for modern world engineering problems. However, multi-variable nonlinear problems require new methods to avoid from getting stuck into local minimums during optimization process [1]. Main motivation in the Evolutionary Algorithms (EA) is to mimic the nature to find optimum solutions to these problems. EA can be evaluated as direct, stochastic and population-based search algorithm. There are three main rules of biological processes which inspire the EA based search algorithms. These are:

* **Continuous evolution process** , which occurs at the most basic level of “source-code” of living beings, i.e. chromosomes
* **Natural Selection mechanism** , in which the fittest individuals in a society can have more chance to survive and have more robust offspring than those who are not fit at all.
* **Evolutionary process at reproduction** , which is done by the reproduction operators such as cross-over and mutation.

EA mimics the natural selection of living beings. Fittest one in the group has more chance to survive and to be selected. Individuals correspond to encoded solutions of the given problem. Every individual has a fitness value which is calculated by objective function of problem. Algorithm itself evaluates the “adaptive skills” of every indivudials according to this fitness value. Least fit individuals are eliminated from the population, hence more adapted and robust individuals exist in the next generations. Fitness value is the only required quantitive information about the individual in EAs , contrary to other search techniques such as gradient based optimization methods, in which derivative information is needed [2]. Another advantage of evolutionary search algorithm is that population based evaluation, which is a big computational load advantage over the conventional search algorithms which sample one individual at a time. This population leveled optimization is more advantageous especially when working with large search spaces [3], [4]. In Fig. 4-1, a classification table of search techniques is given.



Fig. 4-1. Classification of search techniques[1], [4]

The most popular search technique among other techniques in the EA family is the genetic algorithms (GA). In this algorithm, individuals are generally represented as fixed-length bit strings as shown in Fig. 4-2 and Fig. 4-3. Different cell positions in these strings contains information which corresponds to different properties of the individual they represent [4]. Two frequently used operators during the reproduction stage of GA are cross-over and mutation operators. Various “species” or various “solutions” can be obtained during the optimization process by using these two operators. Working principles of cross-over and mutation operators are depicted in Fig. 4-2 and Fig. 4-3, respectively. In cross-over, data interchanges between parents around the crossover point which determined in reproduction stage. However, in mutation random new data is written to randomly selected locus on the selected “chromosome” or “individual”.



Fig. 4-2. Bit string cross-over operation between parent individuals [4]



Fig. 4-3. Bit string mutation operation [4]

Evolutionary algorithms start with the initial population where values of the initial variables are selected randomly by selection operators based on stochastic methods. Successive generations are created based on the selection and the reproduction principles. Population size is preserved throughout the generations. Algorithm stops when termination criterions are satisfied [3], [4]. These criterions can be different conditions such as predetermined fitness value, predetermined number of successive generation or limited time.

Every problem can be solved by using EA as long as it is expressed with a proper fitness function. User should define a fitness function such that generations could converge to optimal solution. Therefore, every necessary parameter and penalty coefficient corresponding to it should exist in the fitness function maybe not equally but in a weighted form [2]. Penalty coefficients and related definitions will be covered in the following sections. Another advantage of EAs is that it can be combined with other conventional search techniques. EAs are utilized in a parallel fashion in order to evaluate the fitness among the candidate solutions, as mentioned before. Because of the high computational burden related to larger search space and hybridization processes, distributed computing gaining attention.

## Genetic algorithms based optimization

## MATLAB GA Toolbox Implementation

## 5MW AFPM generator with optimized design parameters

**References**

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