Genetic algorithm and parallel computing

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Abstract **The paper presents an optimisation algorithm for the geometry of three-phase unscreened high-current busways with solid insulation. A genetic algorithm method and parallel computing were used for this purpose. Moreover, the paper discusses the methodology of defining an objective function to allow for phenomena occurring in static and dynamic states.**

Keywords **electrodynamics, power transmission, genetic algorithms, optimisation methods, parallel computations.**

I. Introduction

The development of computer technologies is reflected in the manner in which they are commonly used at various stages of designing modern systems and devices. It takes a large number of decision variables and complicated mathematical methods to construct the devices that fulfil standards and are characterised by small dimensions, ergonomic shape, as well as very high operating and technical parameters. Complex mathematical models require complicated numeric calculations, which tend to take a lot of time. A large number of independent variables has a considerable effect on the choice of an appropriate optimisation method to determine a globally optimal solution and ensure acceptable accuracy and limited time for calculations [1], [2], [3], [4].

The paper presents an algorithm developed by the author to determine optimal geometric dimensions of a three-phase unscreened high-current busways with solid insulation. A genetic algorithm combined with parallel computing was used to carry out calculations. In work some modifications of the basic genetic algorithm are proposed [1], [4].

II. Objective function

The optimisation criterion was based on the minimisation of a plant's production and operation costs within a specified time to fulfil a range of limitations. The objective function (1) has a financial character and is a function of geometric variables, which condition the size of the cross-section area of a buswayst (investment outlays) and the value of active power losses (operating costs).

$$S(\mathbf{u}) = k_{invest.} + k_{operat} \qquad (1)$$

where: **u** – decision variable vector; $k_{invest.}$ – investment outlays, $k_{operat.}$ – operating costs

The objective function $S(\mathbf{u})$ minimised in the optimisation process must fulfil a range of limitations which include: maximum temperature of a live working conductor T_{Cmax} and an insulator T_{Imax}; maximal electric strength E_{max}; maximal forces F_{max} acting in the stationary state and in short-circuiting conditions; requirements of the standards related e.g. to consequences of occurrence of short-circuit currents and electromagnetic compatibility [1], [4].

III. Electrodynamic calculations

The analyses refer to a three-phase unscreened heavy-current busways with solid insulation, its cross-section being presented in figure 1.

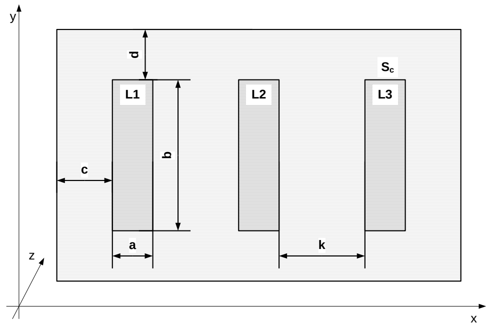

Fig. 1. Cross-section of the high current busway with permanent insulation.

Phase conductors, each of a $\mathbf{S_c}$ cross-section area, are embedded in solid insulation, made out of a component of epoxide resins. The geometry of the system is conditioned by five variables: *a, b* – dimensions of the cross-section of a phase conductor; and *c, d, k* – dimensions determining the distribution of conductors in the insulation.

All electrodynamic calculations start with defining the distribution of current density ***J(x,y)*** in live working conductors with specified phase currents [1], [4]. It can be obtained by solving the system of integral equations (2).

$$\underline{J}(x,y) = -\frac{1}{2\pi} j\omega\mu\gamma \int_S \underline{J}(x',y') \ln \frac{1}{\sqrt{(x-x')^2 + (y-y')^2}} dx'dy'$$
$$\int_{S_c} \underline{J}(x',y') dx'dy' = \underline{I}_c \qquad (2)$$

where: μ – magnetic permeability of the conductor material; ω – pulsation; γ - electrical conductivity of the conductor material; (x, y) – the observation point; (x', y') – the source point; S_c - cross-section area of the conductor.

The distribution of current density and Joule's laws make it possible to define the power losses in phase conductors and then the system temperatures, which condition a busduct's geometric dimensions, which, in turn, determine the ability to carry heat away. The calculations also cover the electric stresses and forces occurring in the system. Other papers present how the equations (2) can be solved and the electrodynamic parameters determined [1], [4].

IV. OPTIMISATION ALGORITHM

The calculation process of the proposed optimisation algorithm is presented in figure 2. The algorithm was developed on the basis of the genetic method where specific operations were used, such as: modified selection as based on remainders, with one repetition; linear scaling of the adaptation function; transferring the best individual from a previous population to the next [3], [4]. Parallel computing was used to shorten the time for searching for the optimal solution. The centralised synchronous implementation of a parallelised genetic algorithm was adopted where one main process manages many subordinate ones, responsible for determining the values of the objective function for particular individuals [3].

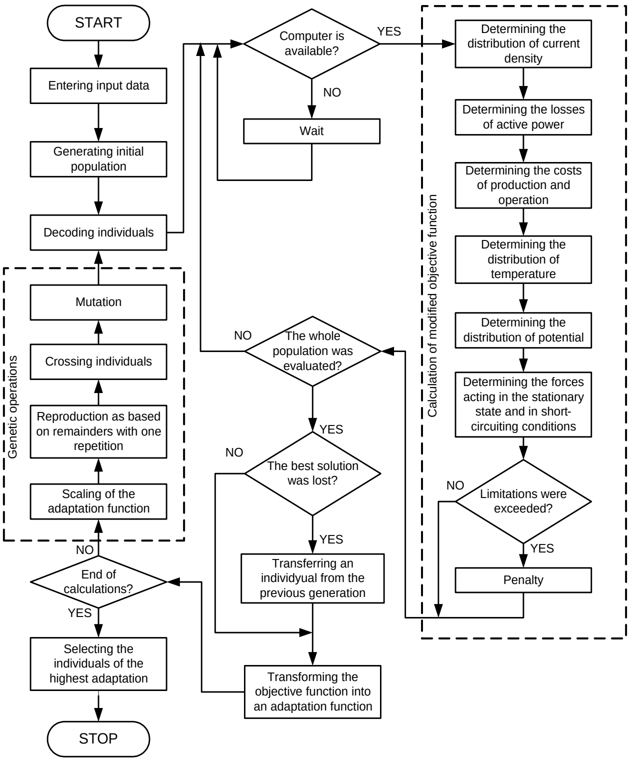

Fig. 2. Optimisation algorithm for high-current busways

It is complex and time-consuming to determine the values of the objective function, requiring a few steps. First, the distribution of current density in phase conductors is defined on the basis of input data and decision variables. Then, active power losses are determined in live working conductors, which serves to specify production and operation costs. The distribution of the thermal power density emitted in phase conductors is used to define an approximate temperature distribution in conductors in an insulator. At the next stage, potential distribution is determined to specify voltage gradients. The last stage of calculating the objective function is to define the forces that act on live working conductors at a nominal load as well as in the state of a short circuit. The permissible values of the parameters being exceeded results in a penalty.

After the values of the objective function have been established for a generation, it is checked whether the condition has been fulfilled for the calculations to be completed. If so, a individual of the best accommodation factor is selected and the solution is implemented.

V. RESULTS OF THE CALCULATIONS

The following were used in the optimisation calculation of the cross section of the current busduct: phase current intensity: 1÷6 kA; conductor voltage: 7,2 kV; operating time: 10 years; conductors made of copper .

The modified genetic algorithm suggested presupposed that the probability of crossing and mutation was 0.75 and 0.006 respectively. A constant size of population was maintained, consisting of 50 specimens. One hundred generations were involved in the optimisation process. The cluster used comprised 20 computers with differently configured hardware, linked by a fast network.

Figure 3 presents the results. The optimisation calculation time on one computer for each case was 32530 seconds approximately. The parallelised algorithm shortened the time to 2900 seconds approximately.

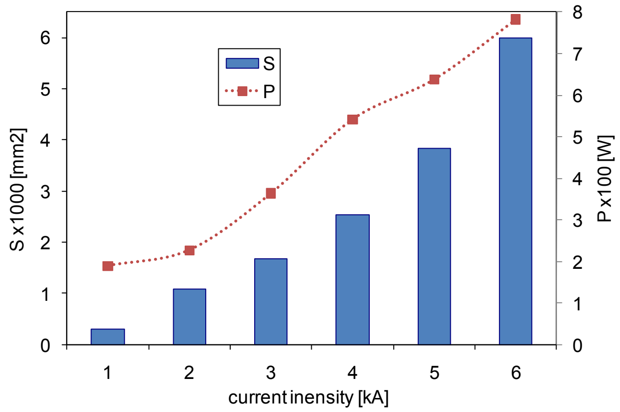

Fig. 3. Relation between the optimal area of a phase conductor cross-section (S_c) and power losses (P) in the function of phase current intensity

VI. CONCLUSION

The results of the calculations showed that the optimisation algorithm used in the multidimensional optimisation of the geometry of the current busway enabled the optimal conditions to be determined and might also prove to be a useful tool to support designing devices other than those mentioned in the article.

The genetic algorithm modifications proposed shortened the searching time to the optimal values in the global sense.

By parallelising the calculation process, it was possible to precipitate the calculations more than eleven times, an attainment that might be of crucial importance when it came to designing an optimal devices within a short time.

VII. REFERENCES

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