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A Computational Tool Focusing the Optimization of 34.5 and 138 kV Overhead Lines Transmissible Power

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In recent years studies concerned with the evaluation of different geometrical configurations for transmission overhead lines, aiming at increasing the transmissible power, have been carried through. These new concepts act in the geometric configuration of the conductors, to search for solutions where the distances among phases tend to reduce, whereas the distances between sub-conductors of the same phase tend to increase. This technology is known as HSIL - High Surge Impedance Loading Line.

The energy supply requirements for emergent regions and specific consumer areas situated far away from an existing electrical substation is the main motivation of this work. This challenge arises the idea of carrying out investigations about the best possible physical configuration for 138 kV and 34.5 kV distribution line that would provide, in addition to the economic and feasible construction limits, conditions to supply such loads.

To reach such objectives, this paper presents the basis and the application of an optimization process using the Genetic Algorithm (GA) to find the best constructive arrangement, while keeping in mind the boundary conditions determined by design and operational criteria, amongst other data. This method uses global optimization codes, based on the mechanisms of natural election and the genetics. These codes use a strategy of parallel and structuralized search, which is random and its main target is to find the best possible result toward a given problem. Although the randomness of the process, it adopts historical information to find new points of search, where better performances are awaited, which, in the focused problem, culminates in a geometric configuration that leads to the highest transmissible power for the distribution line in analysis. The GA approach has already been wide adopted for the determination of the best solution for several electrical engineering problems.

To highlight the approach and its potentiality, a software was developed to represent and simulate any power system including several devices. These are: sources, capacitors, reactors, load and the overhead line. This last one is the main target to the optimization approach through the GA method to obtain the best line physical arrangement and the maximum power transmission capability. At the end, typical 138 kV and 34.5 kV overhead line data are used to illustrate the method. By comparing traditional power transmission limits to the optimized values it is possible to conclude about the advantages of finding better configurations throughout the GA.

The equations that represent the performance of a transmission or distribution overhead line, focusing its power transportation capability are based on the classical π-equivalent circuit illustrated in Fig. 1.

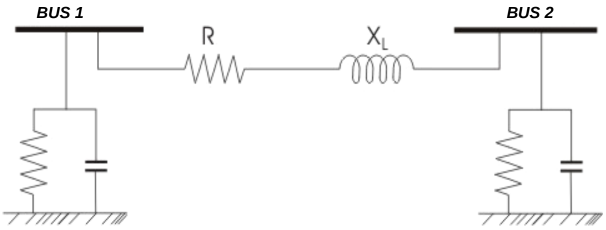

Fig. 1. Typical transmission/distribution line π-circuit representation

The electrical circuit represented by Fig. 1 is bilateral, passive, linear and constituted of two terminals (sending and receiving ends). These characteristics allow these lines to be represented by mathematical quadripoles models. This representation provides great advantages for studying distribution/transmission lines as it is relative simple to insert other parameters or devices, such as: transformer, reactive compensation equipment, other lines, etc.

Then, equation (1) provides the evaluation of the maximum transmitted power:

$$P_{2\max} = \frac{V_1 \cdot V_2}{B} - \frac{A \cdot V_2^2}{B}\cos(\beta_B - \beta_A) \qquad (1)$$

The above equation that will be fully described in the full paper establishes the relationship between the maximum power and the parameters L and C. As such parameters are strongly affected by the constructive arrangements and constitution of the conductors, the search for the best physical configurations for the phases and their sub-conductors are the target of the optimization process. The details of this implementation are presented in the next section.

Aiming at a final product that provides good usability, the developed software, designated by ALPE (High Surge Impedance Loading Line Optimization Software), was developed using Delphi language and the ATP (Alternative Transients Program) platform. Such software is structured as showed in Fig. 2.

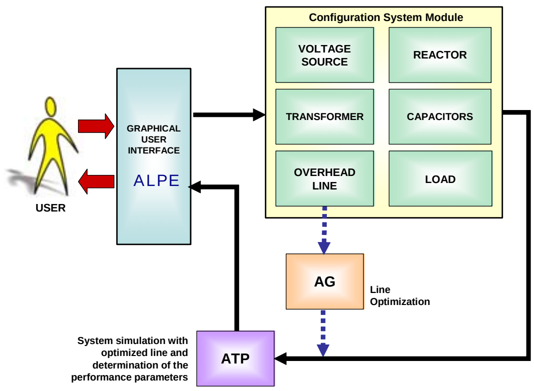

Fig. 2. ALPE Structure

In order to achieve these goals, the final product should prioritize an orienting and friendly graphical user interface. Fig. 3 illustrates an example of a basic power system representation at the ALPE.

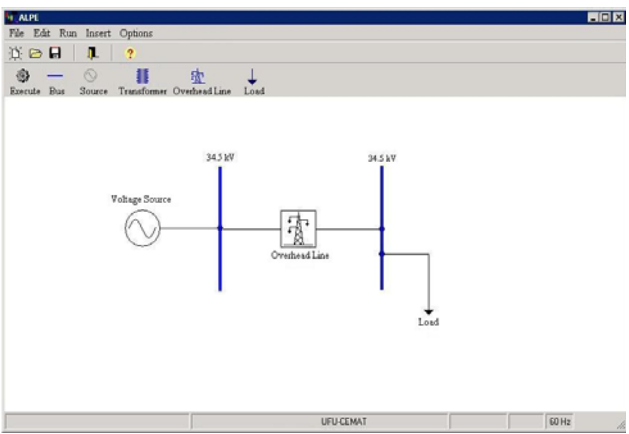

Fig. 3. ALPE – Basic 34.5kV Power System representation

As it can be seen, the ALPE is basically constituted of distinct parts to be fully described in the full paper. These are:

A. *Configuration System Module*

This module is intercommunicated with an optimization package that is based on a search method called Genetic Algorithms which provides the best geometric arrangement by weighting the optimal phase and sub-conductors spacing as well as the line heights aiming at achieving the maximum power at the receiver end.

B. *Optimization of Overhead Lines Designs by Genetic Algorithms*

To cope with the above, mathematical calculations can be implemented to handle overhead lines characteristics and parameters, conductors, phase and sub-conductor spacing, height, etc. These parameters lead to the lines characteristic data (R, L and C) and these, jointly with the voltages, determine the fitness function (1). This equation allows for the calculation of the maximum transmissible active power. The solutions that better satisfy to this equation are called individuals. Such individuals are codified through the concatenation of the mentioned variables in a binary number vector, in which, each set of 10 bits corresponds to specific values for the phase spacing, height and the distance between the sub-conductors, respectively.

C. *ATP Simulator (Alternative Transients Program)*

The mainly elements of the power system were inserted within the typical models of the available library provided by the ATP simulator, with a few particularities added to the sought applications. Thus, after the power system configuration, the ALPE runs the ATP, imports the results and finally shows the electrical performance of the power system under analysis.

To illustrate the achievements and the application of the considered procedure, two power system distribution lines, one of 34.5 kV and another of 138 kV, were taken as examples of distribution lines to be optimized. The final results obtained for the studied cases have pointed out 24% and 34% of power increase for the 34.5 kV and 138 kV lines, respectively.

The method application was carried out to find out the best line constructive configuration as far as phase and sub-conductor spacing and phase's height from the ground are concerned. Although these were the variables chosen to be optimized in this paper, it should be stressed that other variables such as design restrictions, voltage regulation limits, minimum efficiency, thermal limits, mechanical restrictions, economic feasibility, etc could also be simultaneously taken into account. The present work is to be further developed so as to include such conditions.