TAKING IRREGULAR DISTRIBUTION OF POLLUTION AND EVAPORATION COEFFICIENT INTO CONSIDERATION IN DETERMINATION OF INSULATOR SURFACE LEAKAGE CURRENTS

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ABSTRACT

Leakage currents flowing on the insulator surface depend on type and amount of the pollution accumulated on the surface. In this study, insulator leakage currents are simulated with the help of Ant Colony Algorithm (KKA). The pollution layer accumulated on the insulator surface is accepted as pheromones substances of the ants. In regard with this approach, the movement of ants, which are determined based on voltage of each point on the insulator surface, depends on amount of pollution and distance between these points.

In the ant colony algorithm, pheromone substance is laid down to the trail of ants randomly and the amount of pheromone is constantly updated by multiplying with a coefficient of evaporation in order to take the evaporation into account. Similarly, the pollution layer on the insulator surface is distributed irregularly and evaporation coefficient is used to refer to a reduction in the amount of pollution caused by formation of dried bands. These bands are caused by the effect of heat produced by the flow of leakage current. The surface conductivity is calculated from the value of pheromone and the leakage current is calculated from conductivity and voltage difference between points by employing a computer software developed in accordance with this algorithm.

Keywords: High Voltage Insulator, Pollution Flashover, Dynamic Arc Model, Ant Colony Algorithm

1. INTRODUCTION

In energy transmission systems, surface flashovers caused by polluted high voltage insulators can be discussed under two main sections as follows [1-4];

- Coating the surface of insulator with a conductive pollution layer and combustion of pre-discharges in the dry pollution areas formed by heat energy produced by residual currents leaked along the insulator surface,
- Spread of pre-discharges over the surface of polluted insulator

It is observed that the flashover voltage depends on many parameters such as polarity of the voltage [5], type of pollution and size of its particles [3, 6], irregular wetting, surface conductivity, wind, length, profile and diameter of insulator [6] and thickness of the pollution layer [7] under operational conditions.

In the literature, there are two main approaches used for modeling flashover incidence on polluted surfaces: Formation of the minimum voltage necessary to maintain a partial arc ignition series to an unbridged polluted surface that has a varying length [3,5,8,9] and determination and implementation of the criteria required for spread of arc over the surface of wet insulator [3,4].

In addition, solutions have been searched to solve the problem of pollution flashover through calculating residual currents leakages from the surface of insulator and rear series pollution resistance values by conducting studies in the subjects such as model and simulation studies towards determination of flashover voltage [9-14], working on computer software packages to examine the potential and field distributions [3,8,10,11], neural network applications [9,15,16], fuzzy logic applications [17], Ant Colony Algorithm applications [18], the relationship between the length of leakage trail and pollution resistance [3], the time-dependent change of the dry band resistance [9], voltage of the lightning surge and impact of switching (connecting) voltage [10].

2. COMPUTER PROGRAM

The processes given below are performed by the computer program developed for calculation of flashover voltage.

- The voltage value of each node is calculated by assuming that each ant in the node corresponds to a voltage of 1 volt (kka_arfem_giris).
- “kka_anaprogram" subprogram is the part of the main program where KKA is applied. First the initial information is identified and then other subprograms are called within the iteration.
- Coefficients such as node coordinates (x, y), distance information (d_{ij}) and evaporation coefficients are determined by "kka_baslangicbilgileri" subprogram.
- In the iteration, some programs are called such as “kka_ilkyerlestirme” to show that the number of ants placed is as much as potential of the node, “kka_tur”

which maintains movement of all ants depending on distance and conductivity, “kka_yol” which estimates the length of trail advanced by ants for each tour, “kka_guncelleme” which updates the values of conductivity of trails between nodes by taking evaporation into account and “kka_dugumpot” which shows the number of ants therefore their voltage in each stage of the nodes, respectively.

- The best tour held at the end of each iteration is recorded into the series of “besttour”.
- As a result of KKA application, electric field intensity (E_{ARK}) generated by the potential of each node in the model is calculated with the help of the open model of insulator (AR). For nodes on the route of leakage, E_{ARK} and E_D calculated from electric field equation are compared with each other (ab_atlamakriteri).
- Formation of arc between two nodes are determined by the criteria of $E_D > E_{ARK}$. The nodes with generation of arc are balanced. It is checked whether the arc occurs in all nodes.
- If arc is not generated in all nodes, then voltage and conductivity values are updated and we go back to solution subprogram “ab_abdv”.
- If arc is generated in all nodes, then it is determined that the flashover is occurred on the surface of insulator.

The general flow chart of the part of the program where KKA is implemented is presented in Figure 1.

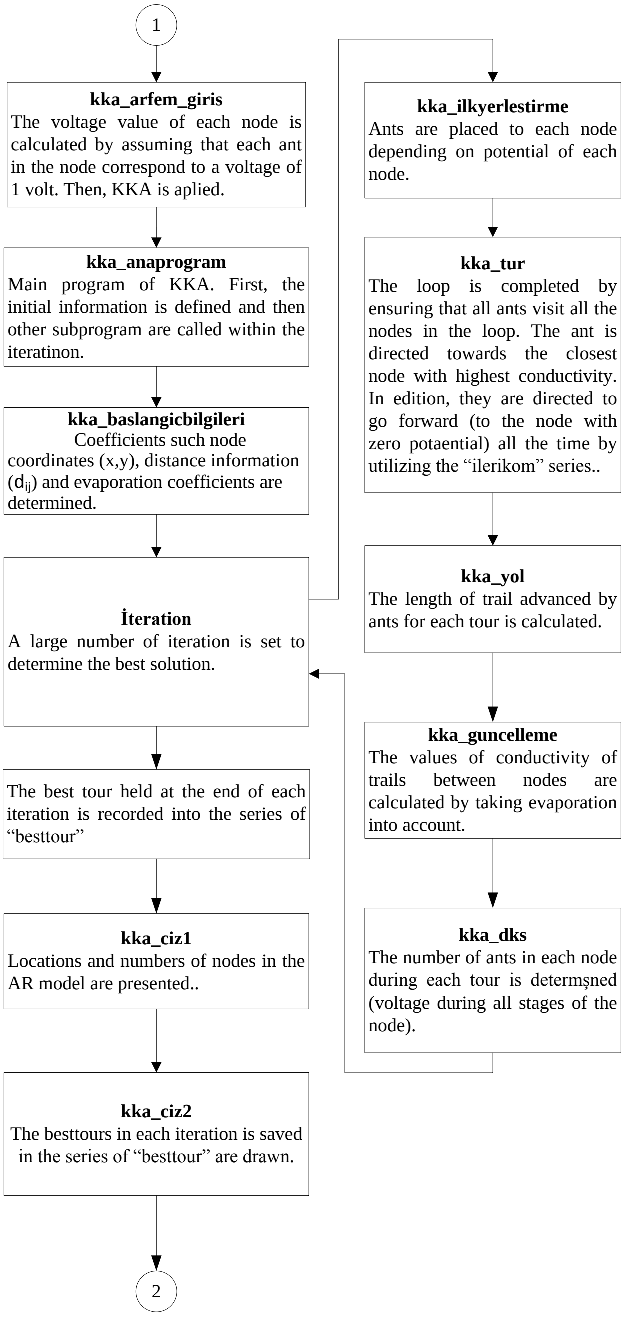

Figure 1. Flowchart of the program for the calculation of surface leakage current

2.1. kka_arfem_giris Sub-program

Voltage values of all nodes are collected to determine the total number of ants. Then, ant colony algorithm is applied by calling “kka_anaprogram” sub-program (Figure 2).

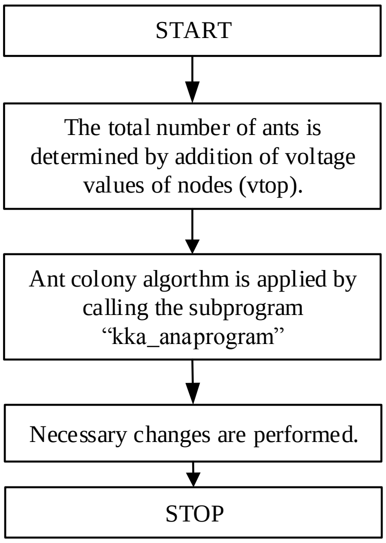

Figure 1. Flowchart for "kka_arfem_giris" sub-program

2.2. kka_anaprog Sub-program

This program is the main program of Ant Colony Algorithm. First, the initial information is determined. Then the other sub-programs of KKA are called within the framework of iteration and the shortest tour is obtained. For drawings of the shortest tour obtained at the end of the iteration, the relevant programs are used (Figure 3).

2.3. kka_ilkyerlestirme Sub-Program

In this sub-program, ants are placed to each node depending on potential of each node. The flowchart for the sup-program is given in Figure 4.

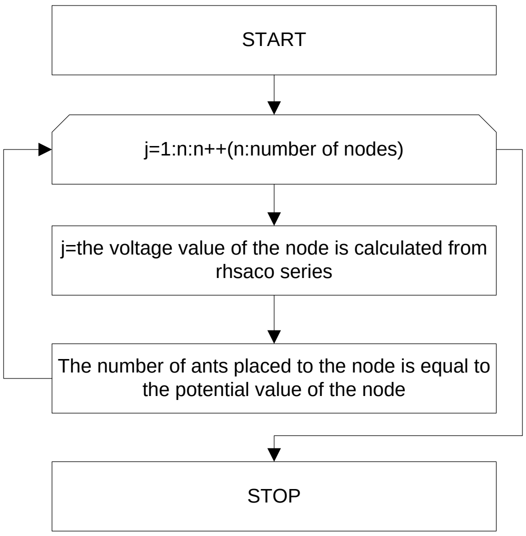

Figure 2.Flowchart for "kka_ilkyerlestirme" sub-program

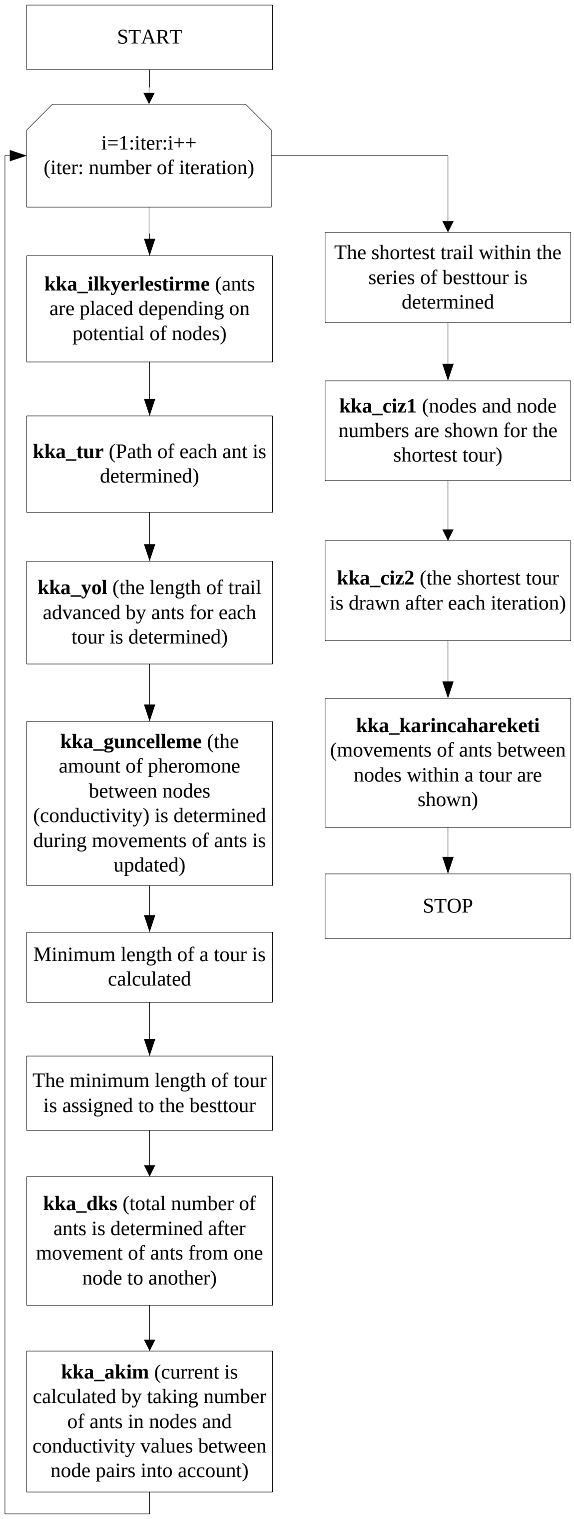

Figure 3. Flowchart for "kka_anaprog"

2.4. kka_tur Sub-program

The loop is completed by ensuring that all ants visit all the nodes in the loop. The ant is directed towards the closest node with highest conductivity. In addition, they are directed to go forward (to the node with zero potential) all the time by utilizing the (ilerikom) series. The tour is completed when the ant arrives the node with zero potential (X(npoin)). These action steps in each iteration is recorded in the (at) series

2.5. kka_ karincahareketi Sub-program

In this sub-program, movements of ants in each step are plotted. To this end, information of the node is obtained from (at) series, where tour information of ants are saved, and coordinates related to these nodes are transferred to xx and yy indexes.

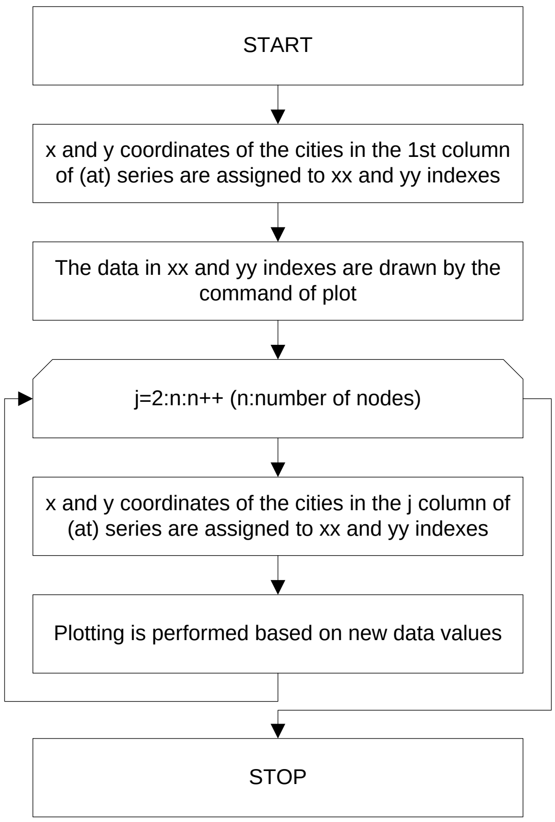

Figure 3. Flowchart for “kka_ karincahareketi” sub-program

3. PROGRAM OUTCOMES

In this study, an algorithm to be implemented in the pollution problem of Ant Colony Algorithm insulators is developed and this algorithm is written in MATLAB (License No: 161051). For this, first, potential distribution of fog-type BSFT 9336 is calculated by finite elements method. Then, open model of this insulator is created (AR model).

The application is implemented on U160 BL type insulator shown in Figure 6. Some technical characteristics of U160 BL type insulator are given in Table 1 [19]. The processes presented below are carried out by computer program developed to calculate flashover voltage, respectively.

Table 1. Properties of U160 BL Insulator

Diameter (D)	Height (H)	Pin Diameter (d)	Leakage Lenght	Weight
280 mm	170 mm	20 mm	390 mm	8.8 kg

Figure 4. Photograph of U160 BL Insulator

Similar to the pheromone substance in the ant colony algorithm, pollution layer is distributed on the surface of the insulator in the “kka_guncelleme” subprogram and a constant evaporation coefficient is taken into account to express the reduction in the amount of pollution by the effect of heat produced as a result of the residual current flows.

In Figures 7 and 8, one of the steps for acquiring Finite Elements in this insulator and
changing curves for field intensity calculated by KKA program prepared in MATLAB are presented.

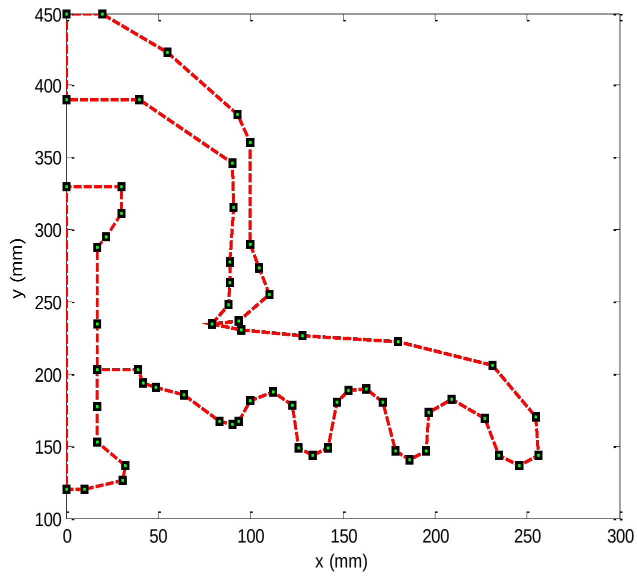

Figure 5.U160 BL insulator shape determined for M=1 (half-symmetry)

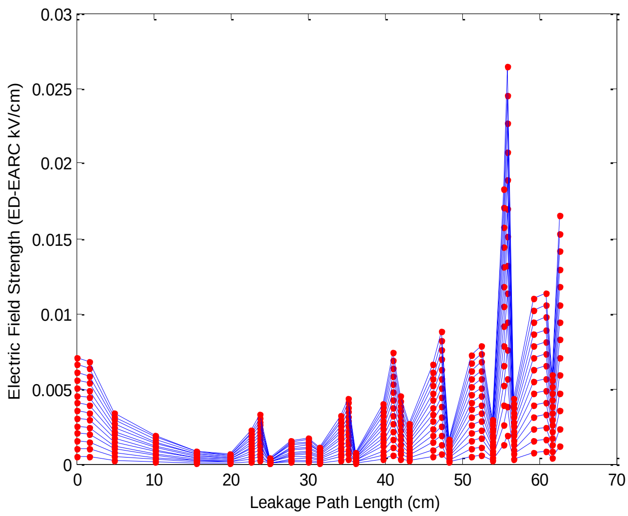

Figure 6. Field strength curves of surface leakage length for U160 BL insulator)

In the experimental system shown in Figure 9, surface current leafages are measured for an insulator that has 10.98 µS conductivity value and current values are calculated by entering the same conductivity value to the computer software (Table 2).

Figure 9. Experimental system

Table 2. The calculating and obtained surface leakage current values of the insulator which have 10.98 µS surface conductivities

Uyg. Ger. (kV)	10,98 µs	
	Hesaplanan I(eff) (mA)	Ölçülen I(eff) (mA)
5	0,187	0,16
10	0,310	0,324
15	0,450	0,452
20	0,560	0,64
25	0,681	0,68
30	0,833	0,756
35	0,906	0,91
40	1,039	1,052
45	1,176	1,216
50	1,285	1,52

4. RESULTS

In this study, theoretical and experimental studies are performed to determine surface leakage currents within the scope of solving the problem of pollution flashover (surface flashover) in an insulator, which is a major cause of failure in high voltage power transmission lines.

In the studies regarding pollution flashover in the insulators, conductivity of pollution layer on the surface of insulator is assumed to be constant in general due to the difficulties in modeling and calculations are performed based on this assumption. In reality, the conductivity of pollution layer on the surface of the insulator has an irregular distribution and varies at every point across the surface. In this calculation method (KKA), which is developed to increase accuracy of modeling, irregular distribution of pollution layer on the surface of the insulator.

In the subsequent stage of the study, behaviors of surface leakage current on the surface of an insulator and surface flashover steps will be explained in detail if evaporation coefficient, which shows the change of conductivity of pollution layer on the surface of insulator with a time variable, is expressed as a function depending on the heat energy produced by leakage currents on the surface.

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