# USING GEOGRAPHICAL INFORMATION SYSTEM TO DEVELOP A TOOL FOR OPTIMAL LOCATING OF FAULT

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## *ABSTRACT*

*In this paper an algorithm is described to optimally locate fault indicators in radial distribution feeders considering the existing switching equipments and feeder configuration. The objective function of the optimization problem is explained.*
*We will then go through the process of taking GIS system into use to develop the optimization tool. Case study results are analysed for a real network.*

## INTRODUCTION

There are very long overhead MV feeders in some areas of Iran, where some of them may reach the length of a hundred kilometres. Most of these feeders pass through arduous roads and areas. Numerous faults are the major operation problem with these feeders. Using fault indicators (FI) is a good solution to locate faulted area. The number and the location of FIs are very important for a fast and accurate locating of faults. Installing a high number of FIs will result in confusion of operators and sometimes extra activity introduced by maloperation of FIs.
In this research an algorithm is developed to optimally locate FIs considering the existing switching equipments and the configuration of the feeder.
System data is available in geographical information system (GIS). A tool can be developed to covert the mass GIS data into an understandable format for the FI locating algorithm.

## MODELLING THE IMPACT OF FAULT INDICATORS IN A DISTRIBUTION FEEDER

When a fault occurs in a distribution feeder, the first step is to locate the fault which may be very time-consuming in long feeders or in feeders with too many t-offs. Faulted area will be isolated using sectionalizers and the remaining parts will be re-energized using adjacent feeders. This process is called energy restoration. The restoration process can be described in three steps considering the time of activities. Figure 1, shows the relation between the three steps of a restoration process [5].

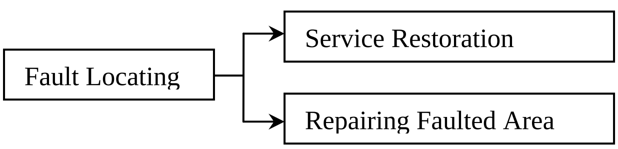



Figure 1- Time-based relation of steps in a restoration process

As can be seen in figure 1, time for location the faulted point plays an important role in the overall restoration period.
Let's consider the network of figure 2, where a distribution feeder with an FI is illustrated.

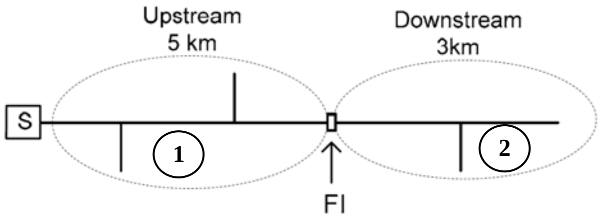



Figure 2- A radial feeder with a fault indicator

Normally, the time required for locating a fault on a radial feeder with no FI is proportional to the length of the feeder. Let's call this time as $T_o$. Installing an FI at the point shown if figure 2, one will not need to examine the whole length of the feeder to locate the fault. In case of a fault on zone 1, required time to locate the fault will be equal to:

$$T_o \times \frac{5}{3+5} = 0.625T_o$$

And for a fault on zone 2, this time will be equal to:

$$T_o \times \frac{3}{3+5} = 0.375T_o$$

Breifely in a radial feeder with n FIs installed throughout the feeder, it will be broken into n+1 zones. Time required to locate the fault in each zone equals:

$$T_i = T_0\left(\frac{L_i}{\sum_{j=1}^{n+1} L_j}\right) \qquad i = 1, 2, 3, 4, ..., n+1 \tag{1}$$

Where;
$T_i$: average time required to locate a fault on the i[th] zone
$T_o$: average time to locate a fault on a feeder with no FI
$L_i$: length of the i[th] zone

## MATHEMATICAL REPRESENTATION OF THE PROBLEM

The objective function of this problem can be described as finding the best location of fault indicators so that the total investment cost of FIs is minimized together with the costs of outages. So, the objective function can be mathematically mdelled as in equation (2) [6].

$$Min \quad F = \sum_{t=1}^{ny} (PW)^t \cdot OC + \sum_{i=1}^{n} FI_i \cdot CFI \tag{2}$$

$$PW = \frac{1 + Infr}{1 + Intr}$$

Where,
*F*: total cost [USD]
*OC*: annual cost of outages [USD]
$FI_i$: a decision parameter describing whether an FI is installed at point i or not
*CFI*: investment cost for purchasing and installing an FI
*n*: number of candidate points for FIs to be installed at
*PW*: an economical coefficient to convert operational costs during system lifetime, to present value
*Infr*: inflation rate
*Intr*: interest rate
*ny*: planning period [year]
As mentioned above, cost of outages needs to be evaluated; This value can be calculated as a sum of outages imposed to substations fed by our target feeder. So:

$$OC = \sum_{i=1}^{nLP} CENS_i = \sum_{i=1}^{nLP} IC_i \cdot ENS_i \cdot K_i \tag{3}$$

Where,
*OC*: cost of energy not supplied to the feeder
$CENS_i$: cost of energy not supplied to the $i^{th}$ substation
$ENS_i$: amount of energy not supplied to the $i^{th}$ substation
$IC_i$: average cost of outage per kwh of energy in the $i^{th}$ substation
$K_i$: a factor taking importance of the $i^{th}$ substation into consideration
*nLP*: number of substations on the target feeder

The parameter $IC_i$ differs from substation to substation and depends on the load behaviour of each substation. It can be calculated as follows:

$$\begin{aligned} IC_i = {} & AIC_i(res) \cdot P_i(res) + AIC_i(com) \cdot P_i(com) + \\ & AIC_i(ind) \cdot P_i(ind) + AIC_i(agr) \cdot P_i(agr) + \\ & AIC_i(gen) \cdot P_i(gen) \end{aligned} \tag{4}$$

Where, $AIC_i(res)$, $AIC_i(com)$, ... correspond to outage cost of each kWh of residential, commercial, industrial, agricultural, and public loads, respectively.
It sould be noticed that, any change in the number and location of FIs will result in different $ENS_i$ as a consequence of a variation in time to locate the fault.

## OPTIMIZATION

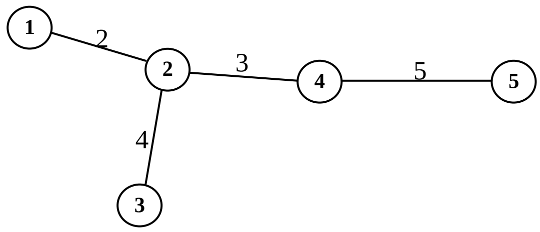
The optimization problem is solved using genetic algorithm, which requires a logical coding of parameters to be solved. Decision variables are described as a string chromosome named D as shown in eauation (5).

$$D = \{FI_1, FI_2, ...., FI_n\} \tag{5}$$

Generation of initial population is accomplished using a normal random generation.

## DEVELOPMENT OF AN APPLICATION PROGRAM

Normally optimization algorithms need a large amount of calculations and analytical activities to come to a conclusion, evidently not possible with hand calculations. A standard application was developed to perform this analysis automatically.
Distribution networks data is available in GIS-based databases. Massive data of a GIS has to be summarized and coded to be understandable for the FI location program. This is performed by developing an interface from GIS system to FI location tool.
To achieve this, we need a standard coding to introduce a network to the program, as input data. Referring to graph theory, a radial feeder can be recognized as a tree. The concept of feeder coding is illustrated in an example network in figure 3, where the number on each edge corresponds to the length of each section. Vertice (1) is the beginning of feeder at source side.




| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1 | 0 | 2 | 0 | 0 | 0 |
| 2 | 2 | 0 | 4 | 3 | 0 |
| 3 | 0 | 4 | 0 | 0 | 0 |
| 4 | 0 | 3 | 0 | 0 | 5 |
| 5 | 0 | 0 | 0 | 5 | 0 |

Figure 3- An example of feeder coding

As mentioned before, data is available in a GIS-based database. So we need to convert graphical (raster) data into numerical coding. The convertor developed to perform this task, asks the user for a selection of target feeder. Then it calculates all beginning/end coordinates of all line segments. These coordinates are analysed using following rules:

- All coordinates which are repeated twice, are junction points.
- All coordinates which are repeated three times or more, are t-offs.
- All coordinates except the source vertices which are not repeated, are end points.
- Length of each segment can be calculated using UTM coordinates given by GIS database

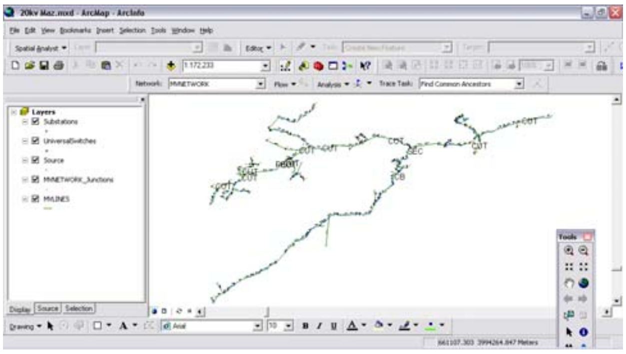


Image 1- Selection of a feeder in GIS

After coding geographical data into the optimization program, the tool will search among feasible solutions to find the best location and number of FIs.
Calculation of ENS for each generation of FIs in the GA process is performed by a reliability module running inside the GA optimization program.
When the optimization comes to a result, the application changes the location of suggested FIs into raster data which is shown as blinking circle on GIS map.
Figure 4, illustrates the process accomplished by the developed tool.

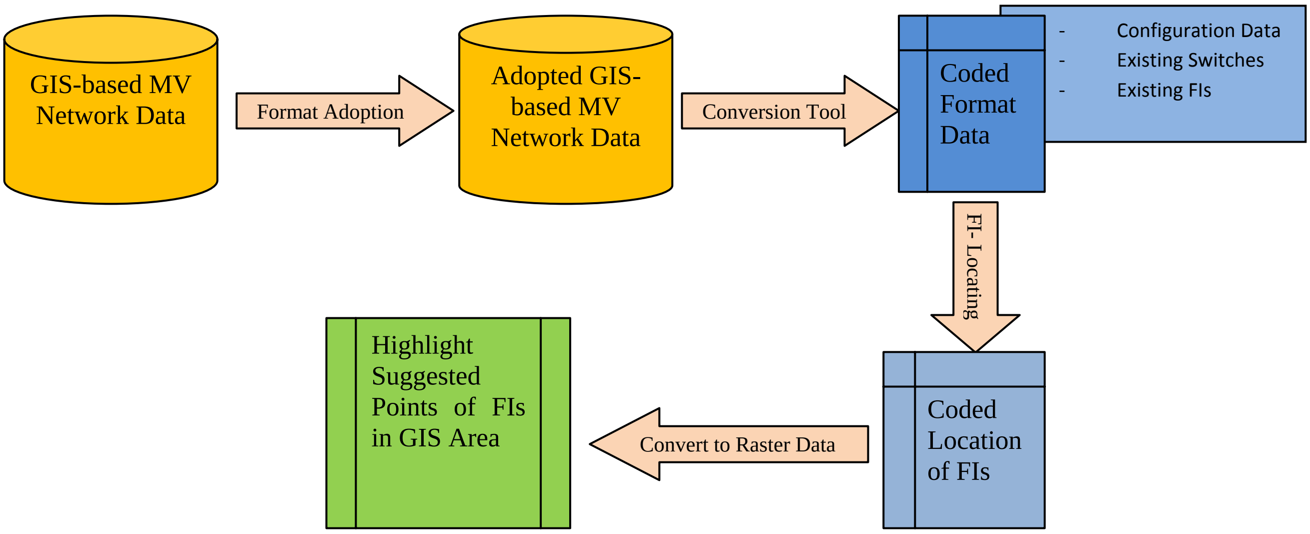



Figure 4- Steps covered by developed application

## CASE STUDY

A case study is performed on a real long feeder. Image 1 shows structural configuration of the test feeder. Technical and economical assumptions are as follows:
Feeder name: ALASHT
Total length: 92.103 km
Number of substations: 55
Maximum load: 2.885 MW
Total consumption: 10000 MWh
Number of adjacent feeders: 3
Number of switching devices: 15
Unit price of Energy: 0.12 $/kWh
Average cost of outage: 0.5 $/kWh
Investment and installation cost of FIs: 800 $
Operational cost of FIs: 50 $/year
The program suggests 3 FIs at positions marked in Image 2. As the study was made on a real network and because of lack of any benchmark figure to check the correctness of results, experts of distribution network operation were asked to give comments on the result. Also 3 FIs are now installed at the suggested points and data is being recorded to be checked after a 2 year period to see whether there is an improve or not.

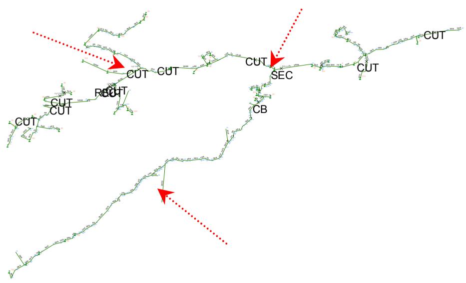


Image 2- Suggested points to install FIs

## CONCLUSION

An algorithm was proposed to find the optimal location of fault indicators in long radial distribution feeders. The algorithm takes ENS as main criteria for decision making. Adapting the problem to be solved by GA algorithm was briefly discussed. Coding of GIS data to the proposed algorithm was explained. A short introduction was made to the developed software application for solving the optimization problem. Finally a case study was made on a real network, where the corresponding results are still being monitored to check improvement of network reliability and operational indices.

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