**Location of Electrical Jointing Using Graph Theory Based on Regulation in Indonesia**

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***Abstract***

*Location of electrical jointing must be known first when there are any problems with the electrical lines in medium voltages. If the location of electrical jointing not yet be known, the response for the problems would be delayed. That problems would be hard when electrical jointing located in the underground. The purpose of this research is to find the location of electrical jointing in underground using graph theory. The lines of underground electricity of medium voltages would be determined based on the installment's regulation from Electricity Company of Indonesia. Installment's regulation would be used as factors that influence the location of electrical jointing in underground. Theory of networks flows can be adapted in this research to analyze the best lines from any possible lines that have been found. Adopted form the graph theory, transmission lines components and surrounding objects (i.e. buildings, road, etc.) would provide vector data which are points, lines, and polygons. These vector data will be processed to be converted to points that can be described as nodes or edges. So that the possibilities lines could be connected from nodes to nodes/edges. Accuracy of electrical jointing location would be compared to the exact location of electrical jointing in underground.*

*Keywords: Electrical Jointing, Graph Theory*

## 1. INTRODUCTION

There are many problems that happen in electrical lines in Indonesia. The problems delay the efficiency of transmitting the electricity to the user in Indonesia. Particularly during the disruption of electricity lines. These are the problems that occurred through the electricity lines:

a. There are many electricity lines that are not registered to the database especially in underground position.
b. The database is not accurate and need to be updated continuously. Yudi, the mapping practitioner of electricity lines, mention that the process of excavation for the installation of electricity lines cost a lot of money and time. In addition, the data is not really accurate because it is depend on the person memory.
c. Bandung City use more open space than underground electrical lines in medium voltages. In 2014, Wawan Gunawan, Manager of Planning Network in Electricity Company of Indonesia,

Bandung, said that they will continue to encourage all repeaters to store the lines into underground in order to minimize the interference of tree branches and kites which often cause power supply disruption. Based on the cost optimization of the company, the standard medium voltages construction guidelines is preferred direct planting system to be applied in Electricity Company of Indonesia.

d. If the problems are occurred in underground lines, the area that contains electrical jointing must be known first. Then another mapping to find the exact electrical jointing is needed too.

The most recent technology for mapping underground utility is Ground Penetrating Radar (GPR). GPR technology using electromagnetic wave (EM). Mooney (2010) established subsurface imaging with multi-channel ground penetrating radar (GPR) to map underground utilities, influence design and planning, and reduce the need for costly and disruptive test pits. Birken (2014) reviewed remote sensing system of underground utilities and explores its utilization in today's commercial devices (GPR) and in research systems that may become commercially available in the next ten years. One of the major difficulties in interpreting GPR is to distinguish radar echoes caused by objects of interest, such as buried utility lines, from the background clutter of echoes generated by other underground objects or by variations in the road bed and soil (Birken, 2014).

The problem using GPR to map underground electrical jointing is taking a lot of time because of limitations of sensor coverage, if the research area is large. Therefore first to do to mapping the underground electrical jointing is to know where the possible lines are. This research constitute the early stages to fix the problems that occurred often in Indonesia using the graph theory. The graph is so named because they can be represented graphically and it is this graphical representation which helps us understand many of their properties (Bondy & Murty, 1976).

## 2. METHODOLOGY

Based on the guidelines book from the Electricity Company in Indonesia, direct planting power line is more preferred methods for planting. In Indonesia, the possible area for direct planting is on road sidewalk or under pedestrian roads. Road sidewalk path can be used to determine many possible electrical jointing lines. Source and terminal must be determined first to connect between substations. Therefore, the road system may be represent any possible lines where the electrical jointing passed from one substation to another substation.

Other properties that will be used in this research is building distribution. Guidelines book from the Electricity company and government policy suggest the area for electrical networks of medium voltage would be planted in the low population. Hence, building distribution become the properties in this research.

This research required data that can be processed using graph theory. The required data is topography map which is consist building distribution and road system. Theory of graph is a pair of sets (V, E), where V is the set of vertices and E is the set of edges, formed by pairs of vertices. E is a multiset, in other words, its elements can occur more than once so that every element has a multiplicity. Often, we label the vertices with letters (for example: a, b, c, ... or v1, v2, …) or numbers 1, 2, … n (Keijo, 2013). Because of properties consideration, weighted set will be added on the graph equation. The equation as follows:

$$G = \{V(G), E(G), W\} \quad (2.1)$$

Where:

G : Simple graph

V(G) : set of vertices

E(G) : set of edge

W : set of weighted value

Simple graph G consist of V that represent crossroad, E that represent road system, and W that represent weighted value from distance from one vertex to another vertex and building density per block. Figure 1 is the illustration of the G and building centroids distribution.

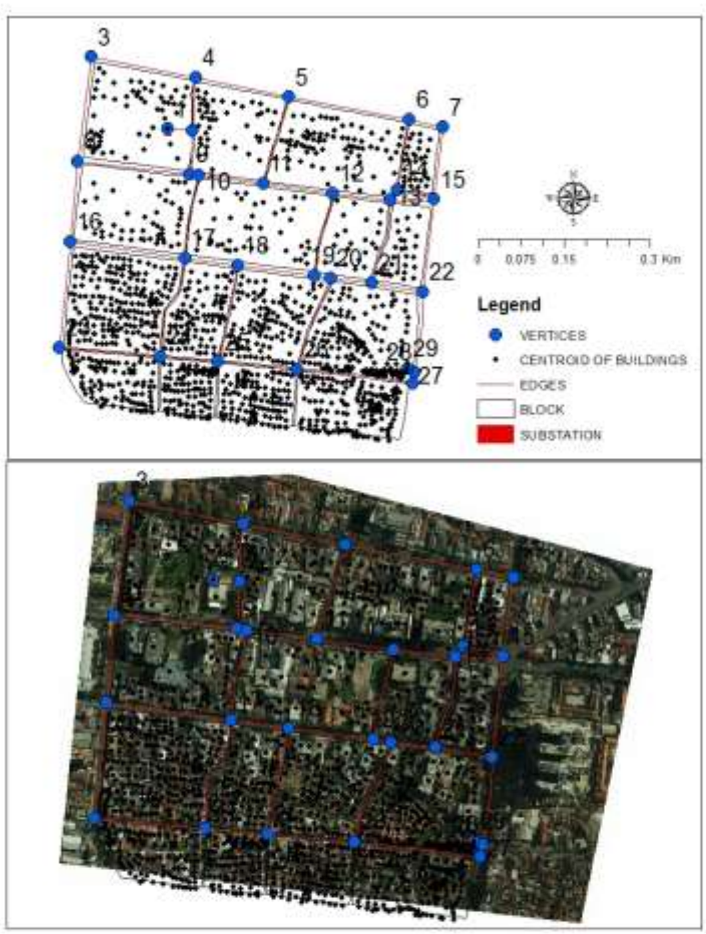


**Figure 1**. Simple graph of G and building centroids distribution

The purpose of this research is to find possible lines where the electrical jointing in the underground was passed. If J is subgraph of graph G, the equation as follows:

$$J = \{V(J), E(J), W\} \quad (2.2)$$

Where:

J : graph of possible lines of electrical jointing passed

V(J) : set of vertices which passed of possible lines

E(J) : set of edges which connected from substation 1 to substation 2

W : weighted value of sum distance and building density from substation 1 to substation 2

Weighted value is determined from multiplication of distance value and building density value, where building density value is calculated as follows:

$$W_{1-i} = \sum_{1-i}(\frac{n_{k_i}}{A_{k_i}} x d_i) \quad (2.3)$$

Where:

*i* : number of edges

*k* : number of block

*n* : sum of building centroid

*d* : Euclidean distance of edges

To identify V and E, algorithm that possible in this simple graph case is djikstra's algorithm. The equation of djikstra's algorithm as follows (Barwaldt, Franzin, Casarin, & dos Santos, 2014):

$$l(u) = d(u_0, u) \text{ for } u \in S_i \quad (2.4)$$

$$l(v) = \min_{u \in S_{i-1}} (d(u_0, u) + w(uv)\} \text{ for } v \in \overline{S_i} \quad (2.5)$$

Where:

*l(u)* : Vertex label

*d,w* : Weighted value

$u_0$ : Vertex in substation 1

$u$ : Other vertices which is adjacent from $u_0$

v :the next vertices/substation 2

Djikstra's algorithm calculated every weighted value from initial node to terminal node. Figure 2 illustrated how the djikstra's equation works.

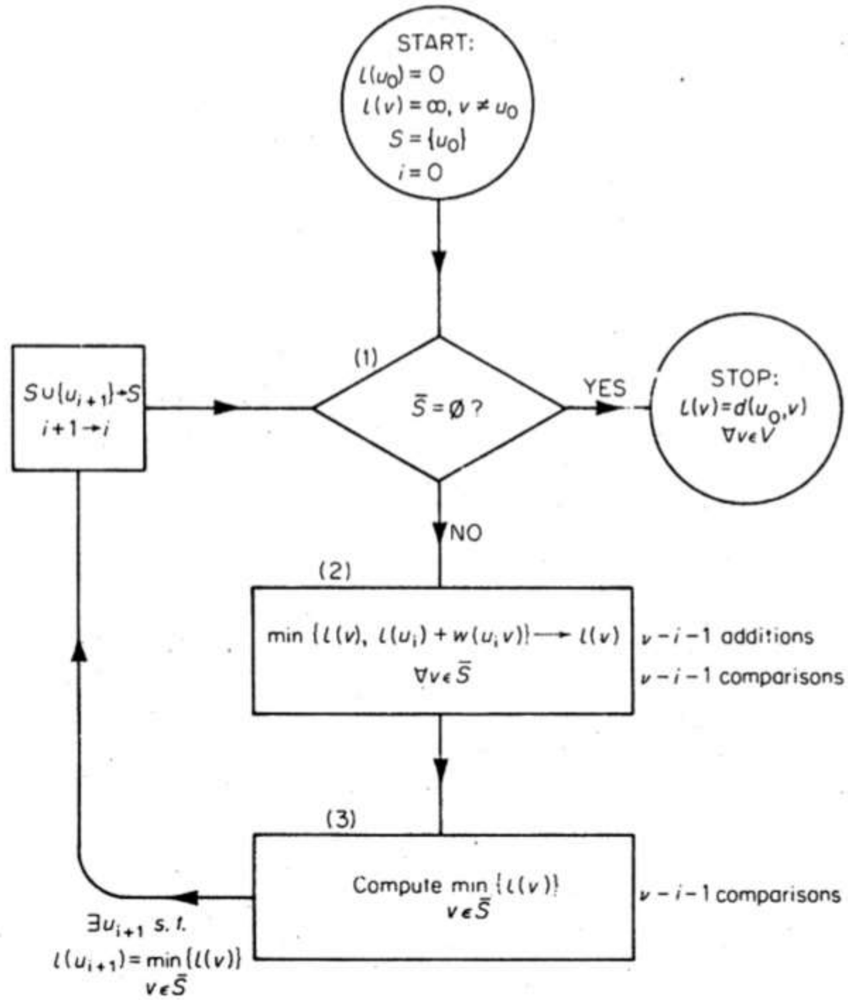


**Figure 2**. Djikstra's Algorithm

(Barwaldt, Franzin, Casarin, & dos Santos, 2014)

The result V(J) consists of L(v) is the expected result in this research. Verification is needed in order to know how well the methodology is. The overall accuracy is a method that will verify the percentage of reliability of the model lines. The model lines carried the vertex label of V(J), and the existing lines also carried the vertex label. Hence, in order to percentage the reliability of the result, overall accuracy will be used to compare each vertex of them.

## 3. RESULT

Vertex label of V(J) is 1, 2, 9, 10, 11, 12, 13, 21, 22, 28, 29. Vertex label of the existing lines is 1, 2, 9, 10, 11, 12, 19, 20, 21, 22, 28, 29. Figure 3 illustrated the difference between the model lines and the existing lines.

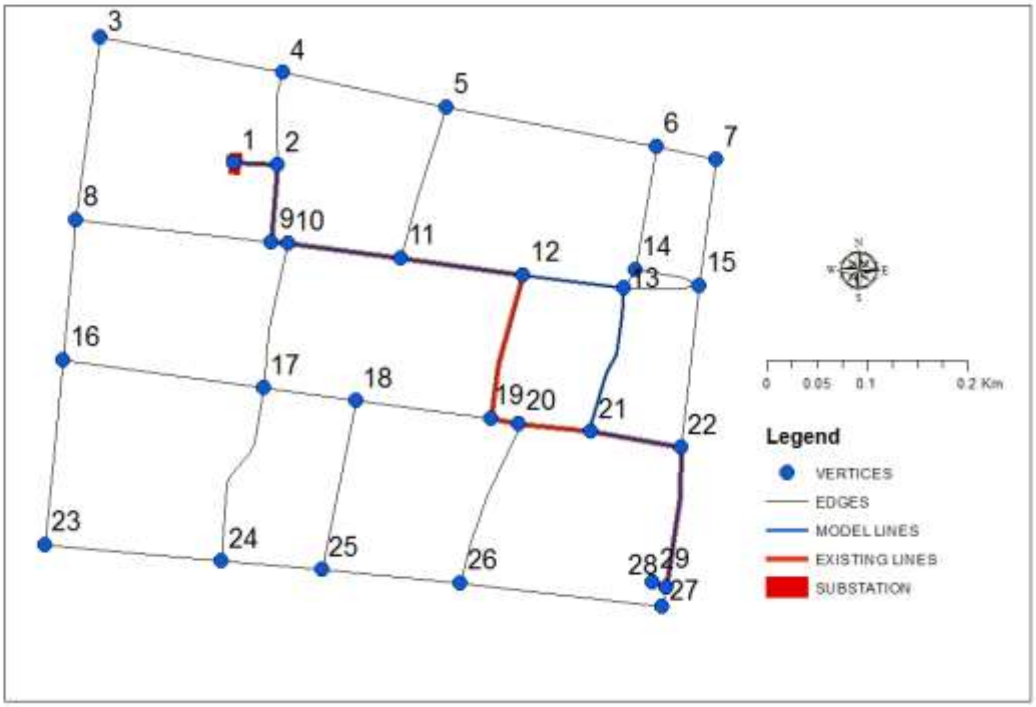


**Figure 3.** Model lines and existing lines

The reliability of the result using overall accuracy is 80%. Table 1 illustrated how much the accuracy of model lines.

**Table 1.** Accuracy of model lines

| overall accuracy | | model lines | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 9 | 10 | 11 | 12 | 13 | 21 | 22 | 28 | 29 |
| existing lines | 1 | 8% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 0 | 8% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 9 | 0 | 0 | 8% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 10 | 0 | 0 | 0 | 8% | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 11 | 0 | 0 | 0 | 0 | 8% | 0 | 0 | 0 | 0 | 0 | 0 |
| | 12 | 0 | 0 | 0 | 0 | 0 | 8% | 0 | 0 | 0 | 0 | 0 |
| | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8% | 0 | 0 | 0 |
| | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8% | 0 | 0 |
| | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8% | 0 |
| | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8% |

Total accuracy of the model lines using graph theory is 80%.

## 4. CONCLUSION

This research constitute the early stages to fix the problems that occurred often in Indonesia using the weighted graph. The output of this research is possible lines from substation 1 to substation 2 where the electrical jointing passed. The weighted value is determined from the shortest distance from substation 1 to substation 2 based on every possible lines in the graph G. Reliability percentage of model lines is 80%. This percentage indicate that the properties that would be used to determine the lines is needed more.

## 5. AUTHOR AND BRIEF BIOGRAPHY

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