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Selection of Remote-Control Tie Switch Installation Location Using AHP-Promethee Method

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ABSTRACT

Remote-Control Tie Switch (RCTS) installation is one of the solutions that can be implemented to increase the reliability of the electric power distribution system. However, installing RCTS at all maneuvered points requires high investment costs, so it is necessary to prioritize locations based on sequence. In this research, there are 79 alternative locations and 5 criteria were used to prioritize RCTS locations. Alternatives based on the criteria produce different preferences, so these preferences must be measured first with Analytical Hierarchy Process (AHP). Then, Preference Ranking Organization Method for Enrichment Evaluation (Promethee) were used to get the location ranking order. The results of the AHP method show that the largest criterion weight is the number of customers (43,43%) and the smallest criterion weight is access to the location (4,64%), with a consistency ratio is 0,0787. The results of the Promethee method obtained the highest net flow value is the AMT02-KDG06 feeder maneuver point (0,415) and the lowest net flow value is the PLH03-PLH04 feeder maneuver point (-0,275). The results of the sensitivity analysis by increasing and decreasing the weight to 5%, 10% and 15% obtained no significant change in the rank position of the location and standard deviation.

KEYWORDS: Tie-Switch, AHP, Promethee, Net Flow, Reliability

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1. INTRODUCTION

In current conditions, electric power utilities are expected by customers to improve the reliability of the electric power supply (Zeineldin et al., 2006)). Customers expect the frequency of interruptions of the power supply to be smaller, if an interruption occurs, the duration of the repair is expected to be fast (Khani & Safdarian, 2020). Therefore, the performance of SAIFI and SAIDI is used by electricity utilities to oversee the achievement of these goals (Willis, 2004); (Billinton & Jonnavithula, 1996)). An effort that can be done is to install a Remote-Control Tie Switch (RCTS). This equipment can reduce the impact of blackouts on customers by maneuvering supply from interrupted feeders to other feeders (Bernardon et al., 2011)). However, installing RCTS at all feeder meeting point locations is not possible because it requires high investment costs ((Georgilakis et al., 2021), so it is necessary to prioritize RCTS installation based on sequence.

In previous research, various methods have been offered to solve the problem of prioritization of switch installations in general. (Bernardon et al., 2011), used the AHP method to determine the installation location with the objective used to minimize Expected SAIDI, SAIFI and ENS. In another hand (Alam et al., 2018), (Moradijoz et al., 2020), (Farajollahi et al., 2019), (Khani & Safdarian, 2020), (Zare-Bahramabadi et al., 2018), (Salyani et al., 2022), (Galias, 2019), using the Mixed-Integer Linear Programming method for determine the optimal switch placement. (Izadi & Safdarian, 2018), (Karimi et al., 2021) using a genetic algorithm. Leite et al., 2019 uses particle swarm optimization to solve it.

In this study, the method that will be used to solve the problem of selecting priority locations for RCTS installation is the AHP-Promethee combination method. Alternatives based on the criteria produce different preferences, so these preferences must be measured first with the Analytical Hierarchy Process (AHP). Then, the Preference Ranking Organization Method for Enrichment Evaluation (Promethee) was used to get the location ranking order. This method was chosen because it is included in the partially outranked method, which can use both qualitative and quantitative data.

2. LITERATURE REVIEW

Remote Control Tie Switch (RCTS)

Switches help customers recover from outages more quickly before troubleshooting, thereby reducing the duration of outages and increasing the reliability of the distribution system (Farajollahi et al., 2019) The switch which is located in the middle of the feeder and acts as a divider for the feeder into many sections is called a sectionalizing switch. A switch that acts as a liaison between feeders to allow sections to be supplied from two sources is called a tie switch. In its application, switches can be operated manually or are referred to as manual switches (MS) and some are equipped with Supervisory Control and Data Acquisition (SCADA) and are referred to as Remote Control Switches (RCS) (Khani & Safdarian, 2020)). Figure 1 shows the location of the RCTS installation.

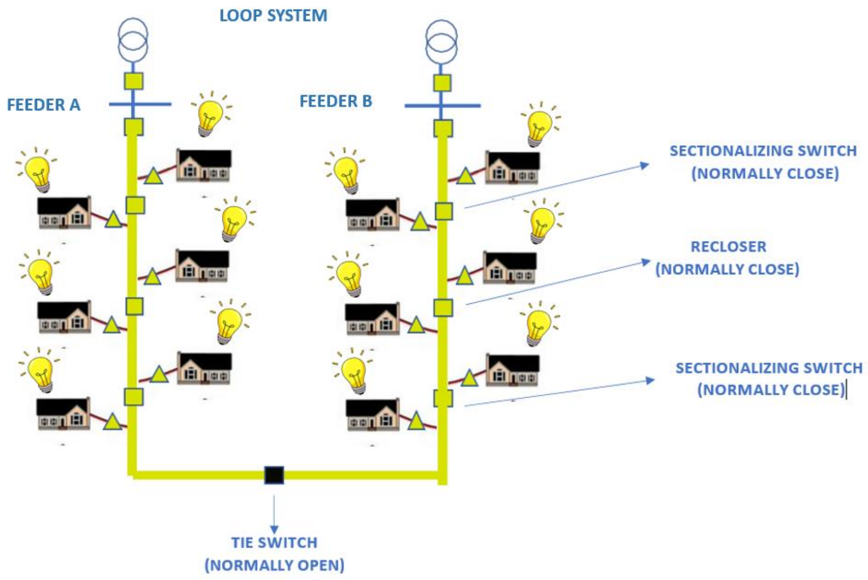

FIGURE 1. RCTS Installation

Analytical Hierarchy Process (AHP)

AHP method was developed in the early 1970s by Thomas L. Saaty, a mathematician from the University of Pittsburg. AHP is also widely used in decisions for many criteria, planning, resource allocation and prioritization of strategies owned by players in conflict situations (Saaty, 1993).

In detail, the process of determining the weight of the criteria for the AHP method can be explainedas follows:

1. Pairwise comparisons determine which is more important and how important a criterion iscompared to other criteria.
2. The results of the pairwise comparisons are then used to determine the pairwise comparisonmatrix as in Equation 1.

$$\begin{bmatrix} c_{11} & c_{12} & c_{13} & .. & c_{1j} \\ c_{21} & c_{22} & c_{23} & .. & c_{2j} \\ c_{31} & c_{32} & c_{33} & .. & c_{3j} \\ \vdots & \vdots & \vdots & . & \vdots \\ c_{i1} & c_{i2} & c_{i3} & .. & c_{ij} \end{bmatrix} \quad (1)$$

3. Add up each column in the pairwise comparison matrix with the formula as in Equation 2. Where n is the number of criteria.

$$C_{ij} = \sum_{i}^{n} = 1\ C_{ij} \quad (2)$$

4. Determine the normalized matrix to get values with the same scale. In this step, the value of each element is divided by the total value per column, with the formula as in Equation 3.

$$x_{ij} = \frac{c_{ij}}{\sum_{i=1}^{n} c_{ij}} = \begin{bmatrix} x_{11} & x_{12} & x_{13} & .. & x_{1j} \\ x_{21} & x_{22} & x_{23} & .. & x_{2j} \\ x_{31} & x_{32} & x_{33} & .. & x_{3j} \\ \vdots & \vdots & \vdots & . & \vdots \\ x_{i1} & x_{i2} & x_{i3} & .. & x_{ij} \end{bmatrix} \tag{3}$$

5. Criteria weight is obtained after determining the average value on the normalized matrix. This weight will be used as a reference in determining the weight in making decisions using the Promethee method. The formula for heavy loads can be seen in Equation 4.

$$x_{ij} = \frac{c_{ij}}{\sum_{i=1}^{n} c_{ij}} = \begin{bmatrix} x_{11} & x_{12} & x_{13} & .. & x_{1j} \\ x_{21} & x_{22} & x_{23} & .. & x_{2j} \\ x_{31} & x_{32} & x_{33} & .. & x_{3j} \\ \vdots & \vdots & \vdots & . & \vdots \\ x_{i1} & x_{i2} & x_{i3} & .. & x_{ij} \end{bmatrix} \tag{4}$$

6. Testing the consistency of the data by calculating the eigen matrix with the formula in Equation

$$e_{ij} = c_{ij} \; x \; w_i = \begin{bmatrix} c_{11} & c_{12} & c_{13} & .. & c_{1j} \\ c_{21} & c_{22} & c_{23} & .. & c_{2j} \\ c_{31} & c_{32} & c_{33} & .. & c_{3j} \\ \vdots & \vdots & \vdots & . & \vdots \\ c_{i1} & c_{i2} & c_{i3} & .. & c_{ij} \end{bmatrix} x \begin{bmatrix} w_{1j} \\ w_{2j} \\ w_{3j} \\ \vdots \\ w_{ij} \end{bmatrix} = \begin{bmatrix} e_{11} & e_{12} & e_{13} & .. & e_{1j} \\ e_{21} & e_{22} & e_{23} & .. & e_{2j} \\ e_{31} & e_{32} & e_{33} & .. & e_{3j} \\ \vdots & \vdots & \vdots & . & \vdots \\ e_{i1} & e_{i2} & e_{i3} & .. & e_{ij} \end{bmatrix} \tag{5}$$

7. Calculating the weighted sum value with the formula as in Equation 6

$$cv_i = \sum_{j=1}^{n} e_{ij} = \begin{bmatrix} cv_1 \\ cv_2 \\ cv_3 \\ \vdots \\ cv_i \end{bmatrix} \tag{6}$$

8. Calculating eigen value with the formula as in Equation 7

$$\lambda_i = \frac{cv_i}{w_i} \tag{7}$$

9. Calculating the eigen value max (λmax) with the formula as in Equation 8

$$\lambda_{max} = \frac{\sum_{i=1}^{n} \lambda_i}{n} \tag{8}$$

10. Calculating the value of the consistency index (CI) with the formula as in Equation 9.

$$\mathrm{CI} = \frac{\lambda_{max} - \mathrm{n}}{n-1} \tag{9}$$

11. Calculating the value of the consistency ratio (CR) with the formula as in Equation 10.

$$CR = \frac{CI}{IR} \tag{10}$$

12. If the CR value is less than 0.1 or 10%, then it can be said that the weight criteria is consistentand can be used to calculate the order of selecting RCTS installation locations using the Promethee method.

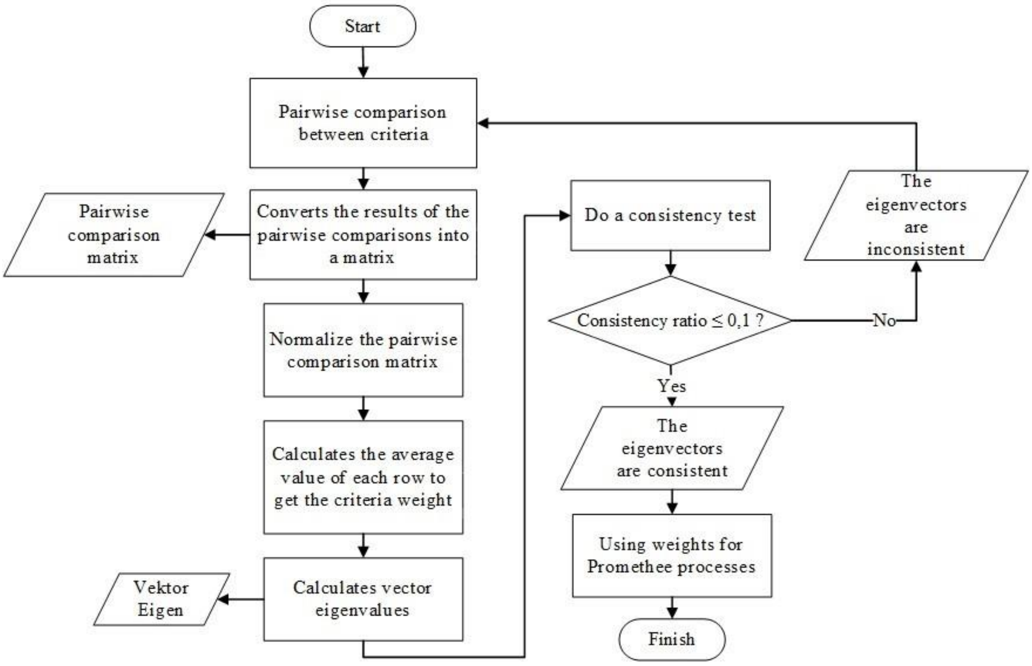

FIGURE 2. AHP Process Flowchart

Promethee

Preference Ranking Organization Methode for Enrichment Evaluation (Promethee) is one of the ranking methods in Multi Criteria Decision Making (MCDM). Promethee is a method of determining the order (priority) in multi-criteria analysis. The hypothesis of the dominance of the criteria used in Promethee is the use of values in outranking relationships. In this research, the Promethee method was used to obtain the order of selecting RCTS installation locations.

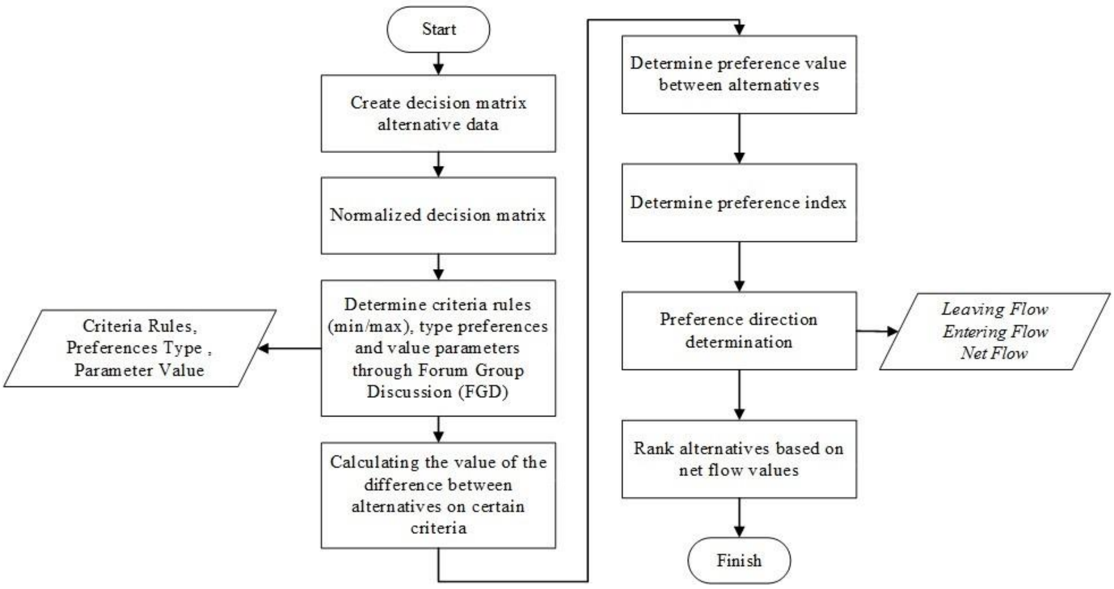

FIGURE 3. Promethee Process Flowchart

In detail, the process of obtaining the location order for RCTS installation can be explained asfollows:

1. Determine the decision matrix of each alternative and criteria.

$$\begin{bmatrix} c_{11} & c_{12} & c_{13} & .. & c_{1j} \\ c_{21} & c_{22} & c_{23} & .. & c_{2j} \\ c_{31} & c_{32} & c_{33} & .. & c_{3j} \\ \vdots & \vdots & \vdots & . & \vdots \\ c_{i1} & c_{i2} & c_{i3} & .. & c_{ij} \end{bmatrix} \quad (11)$$

2. Determine the normalized matrix to get values with the same scale. In this step, the value of each element is divided by the total value per column, with the formula as in Equation 12.

$$x_{ij} = \frac{c_{ij} - min_{ij}}{max_{ij} - min_{ij}} = \begin{bmatrix} x_{11} & x_{12} & x_{13} & .. & x_{1j} \\ x_{21} & x_{22} & x_{23} & .. & x_{2j} \\ x_{31} & x_{32} & x_{33} & .. & x_{3j} \\ \vdots & \vdots & \vdots & . & \vdots \\ x_{i1} & x_{i2} & x_{i3} & .. & x_{ij} \end{bmatrix} \quad (12)$$

3. Determine the criteria rules (min/max), preference types and parameter values for each preference type. To determine this, a Forum Group Discussion (FGD) was conducted with experts who have the qualifications.
4. Calculating the difference between one criterion data and another with the formula as in Equation 13.

$$d_j(a,b) = x_j(a) - x_j(b) \quad (13)$$

5. Determine the preference values between alternatives on all criteria based on the specified preference type function formula. For preference type 3, the formula used is as in Equation 14.

$$P(d) = \begin{cases} 0 \; if \; d \leq 0 \\ \frac{d}{p} \quad if \; 0 < d \leq p \\ 1 \; if \; d > p \end{cases} \quad (14)$$

6. Determine the preference index with the formula as in Equation 15.

$$\pi(a,b) = \sum_{j-1}^{k} P_j(a,b).w_j \quad (15)$$

7. Determine the preference direction by calculating the values of leaving flow (Equation 16), entering flow (Equation 17) and net flow (Equation 18)

$$\Phi^+(a) = \left[\frac{1}{n-1}\right] \sum_{x \in A} \wp\,(a,x) \quad (16)$$

$$\Phi^-(a) = \left[\frac{1}{n-1}\right] \sum_{x \in A} \wp\,(x,a) \quad (17)$$

$$\Phi(a) = \Phi^+(a) - \Phi^-(a) \quad (18)$$

8. Alternative priority ordering based on the largest net flow.

3. METHODS

This study uses a data source from one of the electric power utilities in Indonesia. The data used includes criteria data and alternative location data. Criteria data includes data on the number of subscribers, feeder load, failure rate, access data to locations and telecommunications network connection data. While the alternative data is an alternative plan for RCTS installation locations. All data used is secondary data. The location access data and telecommunications network connections are confirmed according to the qualitative method. In the outline the flow of research can be explained in Figure 4.

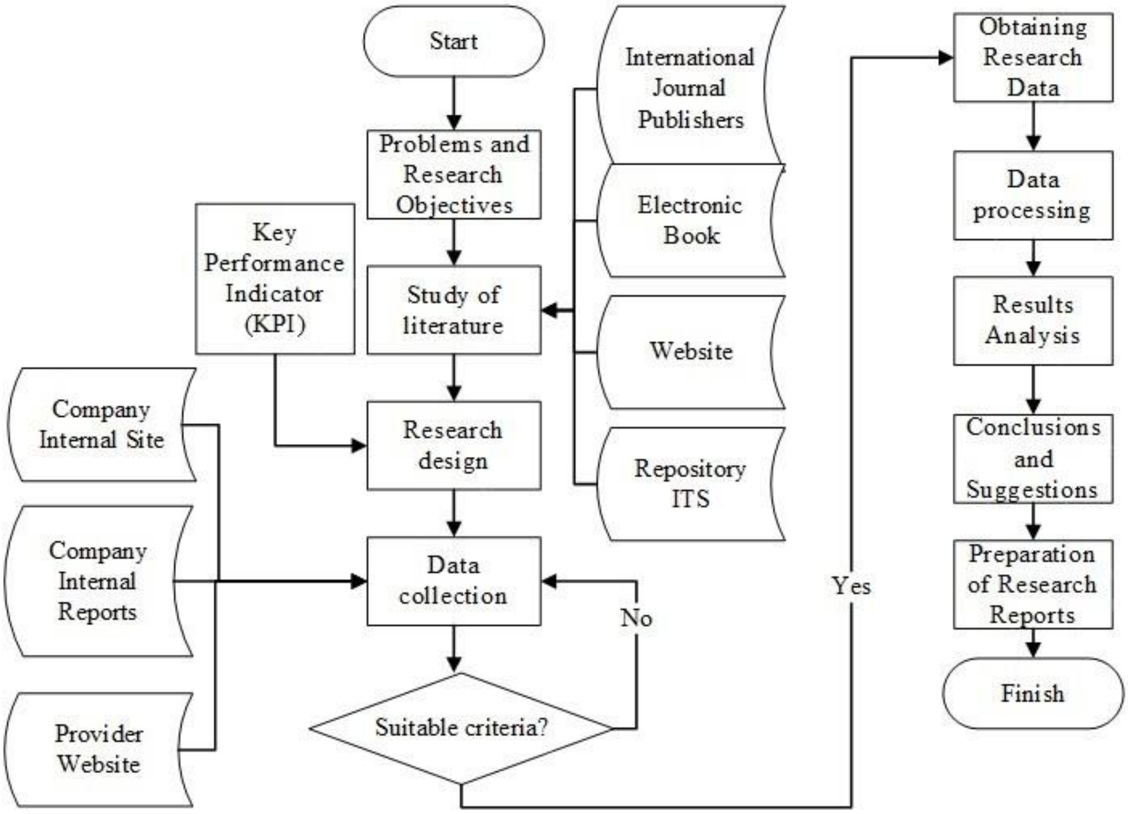

FIGURE 4. Research Flowchart

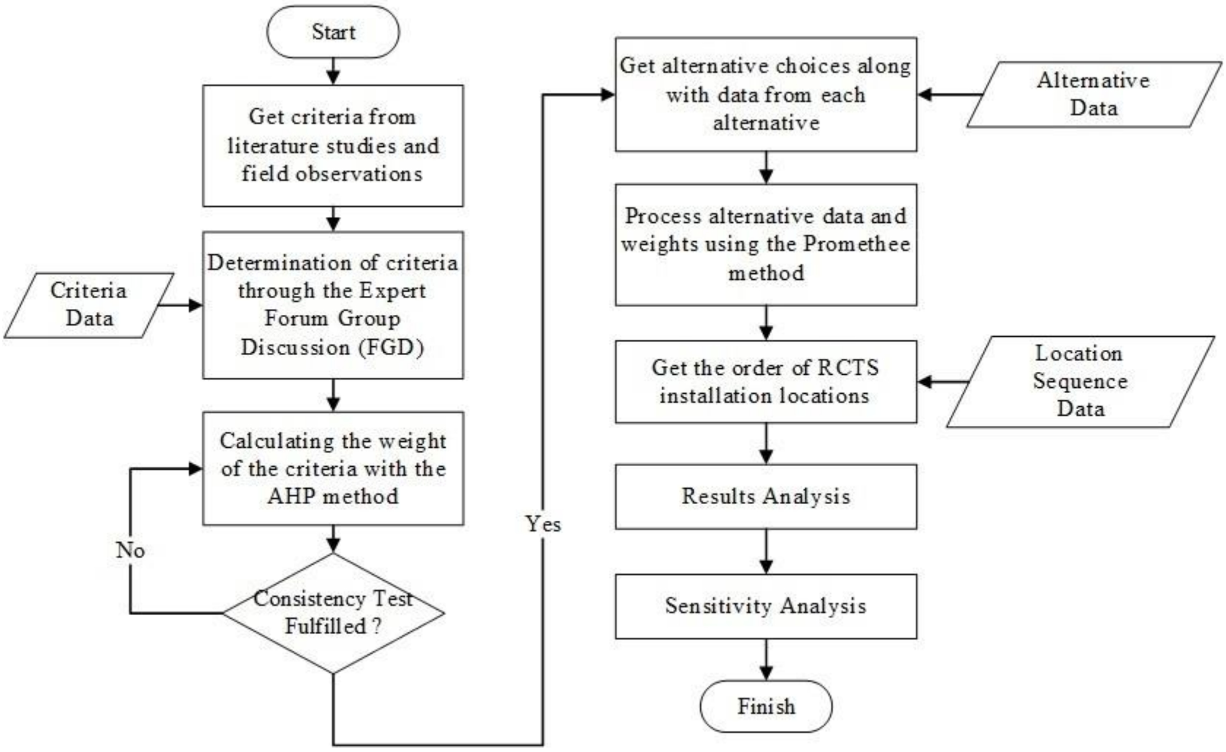

FIGURE 5. Data Processing Flowchart

At the data processing stage (Figure 5), the RCTS installation criteria obtained from the results of the literature study were then confirmed for suitability through a Forum Group Discussion process with qualified experts. Then the criteria for the results of the FGD process were calculated for weightusing the AHP method. Figure 6 describes the AHP hierarchy of RCTS installation criteria.

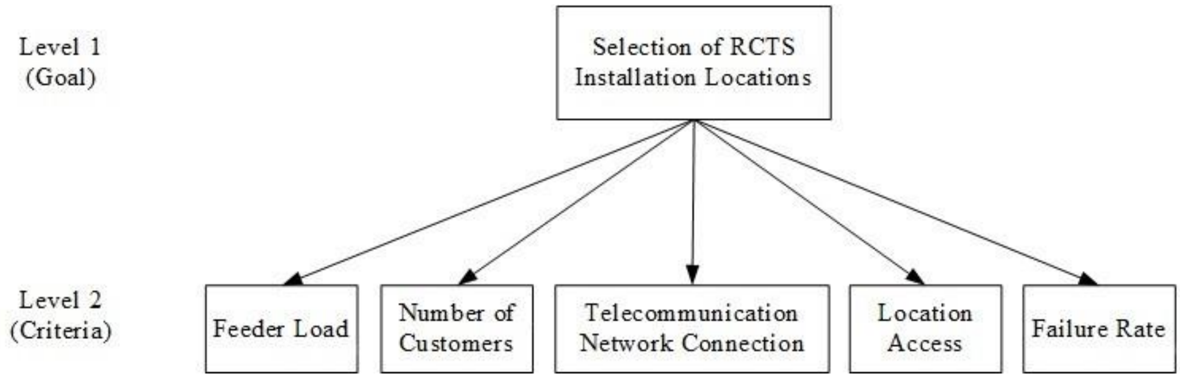

FIGURE 6. AHP Criteria Hierarchy

After the weight of the criteria is obtained, then determine alternative RCTS installation locations. By observing the single line diagram, 79 alternative RCTS installation locations were obtained. Furthermore, to get the order of priority locations for installing RCTS, it is processed using the Promethee method. To ensure the robustness of the research results, an analysis of the effect of changes in the value of the p parameter on changes in the rank position of the alternatives is used and sensitivity analysis is used.

4. RESULTS

The criteria that have been obtained from the FGD results will be carried out by a pairwise comparison process. Table 1. Shows the results of the pairwise comparison criteria.

TABLE 1. Pairwise Comparison Criteria

Criteria				Importance?	Scale
i	j	A	B	A or B	(1-9)
1	2	Feeder Load	Failure Rate	B	1
1	3	Feeder Load	Number of Customers	B	3
1	4	Feeder Load	Location Access	A	5
1	5	Feeder Load	Telecommunication Network Connection	B	2
2	3	Failure Rate	Number of Customers	B	2
2	4	Failure Rate	Location Access	A	4
2	5	Failure Rate	Telecommunication Network Connection	A	3
3	4	Number of Customers	Location Access	A	7
3	5	Number of Customers	Telecommunication Network Connection	A	5
4	5	Location Access	Telecommunication Network Connection	B	3

By processing the pairwise comparison using the AHP method, the weight of each criterion is obtained as shown in Figure 7.

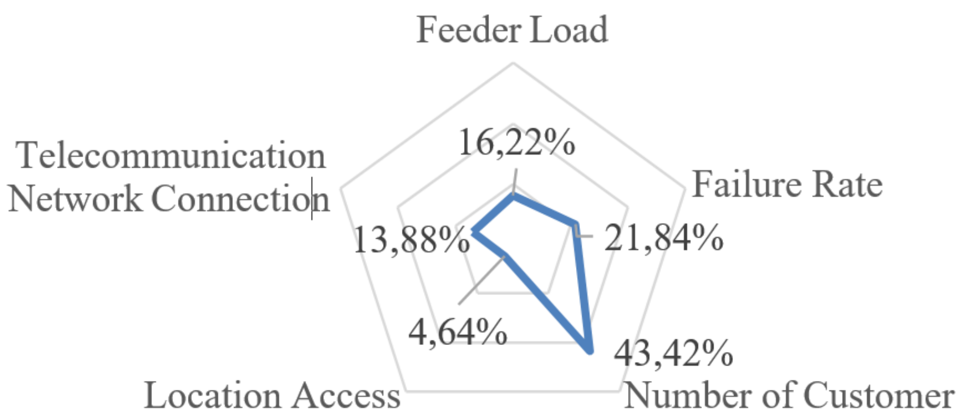

FIGURE 7. RCTS Installation Criteria Weight

The criterion with the largest weight is the number of customers with a weight of 43,42%, the criterion with the smallest weight is 4,64%. To test the consistency of these weights, the calculation of the consistency ratio is obtained as follows:

$$CR = \frac{CI}{IR} = \frac{0{,}08817}{1{,}12} = 0{,}07873$$

With respect to the CR value <0,10, it can be concluded that the results of the pairwise comparisonscarried out in this study are consistent and the weights obtained above can be used to prioritize the RCTS installation using the promethee method. The preference type, rule and parameter p used in promethee method can be seen in Table 2.

TABLE 2. Preference Type, Rule, and Parameter p for Promethee

No	Criteria Code	Criteria	Preference Type	Rule (Min/Max)	Parameter p
1	C1	Feeder Load	III	Max	1
2	C2	Failure Rate	III	Max	1
3	C3	Number of Customers	III	Max	1
4	C4	Location Access	III	Max	1
5	C5	Telecommunication Network Connection	III	Max	1

By processing alternative location data using the promethee method, with the weights obtained fromthe AHP process, the results of the sequence of RCTS installation locations can be seen in Table 3 and Figure 8.

TABLE 3. The Sequence of RCTS Installation Locations

Rank	No Alternatives	Net Flow
1	33	0,415
2	74	0,396
3	40	0,292
4	66	0,282
5	32	0,278
6	56	0,263
7	44	0,222
8	4	0,194
9	65	0,181
....		
79	21	-0,275

FIGURE 8. RCTS Installation Location Based on Net Flow

To ensure the robustness of the research results using the AHP and Promethee methods, a sensitivity analysis was carried out by changing the largest weights to ascending and descending from 5%, 10% and 15%, as well as analyzing the effect of changing the value of the parameter p on changing the rank of the order of RCTS installation locations.

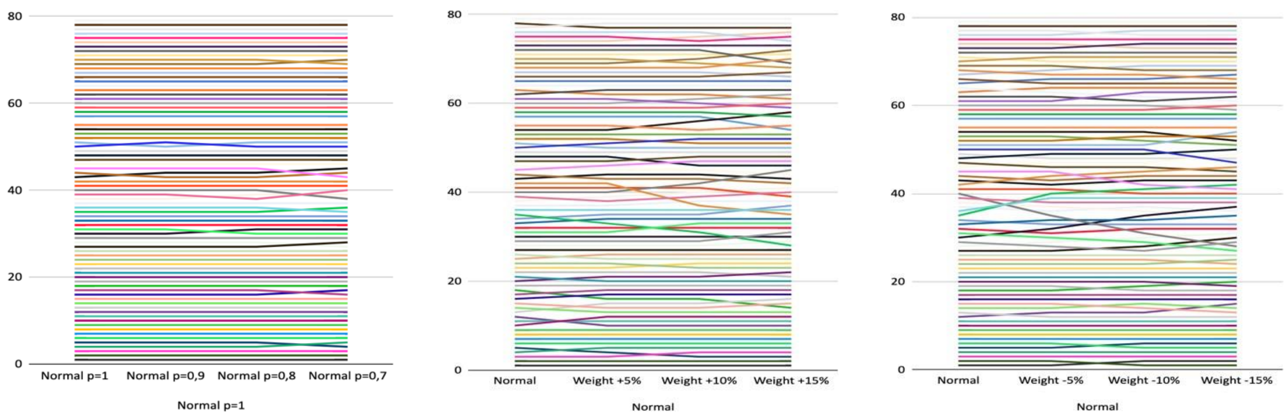

FIGURE 9. Effect of Changes in Weight and Parameter Value of p on Location Rank

The results of the analysis show that by changing the weight and value of the parameter p, it does not show a change in the rank of the installation order of RCTS locations, the maximum change in standard deviation is only 2,28% from normal conditions.

5. CONCLUSIONS

From the research results it can be concluded that the criteria that can be used to determine the location of RCTS installation are feeder load, failure rate, number of customers, location access and telecommunication network connection. The criterion with the largest weight is the number of customers with a weight of 43,42%, the criterion with the smallest weight is 4,64%. The Consistency Ratio is < 0,1 or at 0,078, so the weight of the criteria is consistent. There are 79 alternative locations obtained through single line diagram observation stages. The alternative with the highest net flow with a value of 0,415 is in the 33rd alternative, namely the AMT02-KDG06 maneuver point and the lowest net flow with a value of -0,275 in the 21st alternative feeder, namely the PLH03-PLH04 maneuver point. Changes in the value of the parameter p, the largest increase and decrease in weight does not affect the rank of the order of the RCTS installation location.

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