International Journal of Latest Research in Engineering and Technology (IJLRET)
ISSN: 2454-5031
www.ijlret.com || Volume 12 - Issue 03 || March 2026 || PP. 31-34

Integrated Topsis–Entropy Approach for Optimal Selection of Copper Conductors

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Abstract: The selection of electrical conductors plays a critical role in the design and implementation of electrical systems, directly affecting system reliability, efficiency, and safety. However, this process is inherently complex due to the diversity of available products with varying technical specifications and costs. This study proposes an integrated TOPSIS–Entropy approach to identify the optimal copper conductor among 28 alternatives provided by a supplier. Nine criteria are considered, including nominal cross-sectional area, number of strands, strand diameter, insulation thickness between strands, sheath thickness, overall diameter, maximum DC resistance at 20°C, mass per unit length, and cost. The Entropy method is employed to objectively determine the weights of the criteria, followed by the application of TOPSIS to rank the alternatives. The results demonstrate that product code 20255114 is the most suitable option.

Keywords: copper conductor selection, MCDM, TOPSIS, Entropy

1. Introduction

The selection of electrical conductors is a fundamental step in electrical system design and installation, as it significantly influences operational safety and equipment longevity. Copper conductors are widely preferred due to their superior electrical conductivity, mechanical robustness, and thermal stability.

Despite these advantages, selecting an appropriate conductor is challenging because of the wide range of available products and technical parameters. Engineers must evaluate multiple criteria simultaneously, such as conductor geometry, insulation characteristics, and economic factors.

To address this complexity, multi-criteria decision-making (MCDM) methods have been widely adopted. Among them, TOPSIS is one of the most commonly used techniques due to its simplicity and effectiveness. However, determining appropriate weights for criteria is crucial. In this study, the Entropy method is employed to derive objective weights based on data variability.

2. Methodology

2.1. Entropy Method

The determination of criteria weights using the Entropy method is carried out according to the following steps [8].

Step 1: Construct the decision matrix with *m* rows and *n* columns as shown in Equation (1), where *m* and *n* denote the number of alternatives and the number of criteria, respectively. Let yijy_{ij}yij represent the value of criterion *j* for alternative *i*. The letters **B** and **C** denote benefit criteria (the larger, the better) and cost criteria (the smaller, the better), respectively.

$$Y = \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & xy_{22} & \cdots & y_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ y_{m1} & y_{m2} & \cdots & y_{mn} \end{bmatrix} \tag{1}$$

Step 2: Determine the normalized values of the criteria using Equation (2).

$$p_{\mathrm{ij}} = \frac{y_{\mathrm{ij}}}{m + \sum_{i=1}^{m} y_{\mathrm{ij}}^2} \tag{2}$$

Step 3: Compute the entropy value for each criterion using Equation (3).

$$e_{\mathrm{j}} = -\sum_{i=1}^{m}\left[p_{\mathrm{ij}} \times \ln(\mathrm{p}_{\mathrm{ij}})\right] - \left(1 - \sum_{i=1}^{m} p_{\mathrm{ij}}\right) \times \ln\left(1 - \sum_{i=1}^{m} p_{\mathrm{ij}}\right) \tag{3}$$

Step 4: Calculate the weight of each criterion using Equation (4).

$$w_j = \frac{1 - e_j}{\sum_{j=1}^{m}(1 - e_j)} \tag{4}$$

2.2. TOPSIS Method

The implementation steps of the TOPSIS method are described as follows [9].

Step 1: Same as Step 1 of the Entropy method.

Step 2: Determine the normalized values using Equation (5).

$$y_{ij}^{'} = \frac{y_{ij}}{\sqrt{\sum_{i=1}^{n} y_{ij}^{2}}} \qquad (5)$$

Step 3: Construct the weighted normalized decision matrix using Equation (6).

$$Y = w_j . y_{ij}^{'} \qquad (6)$$

Where w_j is the weight of criterion *j*.

Step 4: Determine the positive ideal solution A^+ and the negative ideal solution A^- using Equations (7) and (8).

$$A^{+} = \{y_1^{+}, y_2^{+}, \dots, y_j^{+}, \dots, y_n^{+}\} \qquad (7)$$

$$A^{-} = \{y_1^{-}, y_2^{-}, \dots, y_j^{-}, \dots, y_n^{-}\} \qquad (8)$$

Where y_j^+ and y_j^- represent the best and worst values of criterion *j*, respectively.

Step 5: Calculate the separation measures S_i^+ and S_i^- using Equations (9) and (10).

$$S_i^{+} = \sqrt{\sum_{j=1}^{n} \left(y_{ij} - y_j^{+}\right)^2} \qquad i = 1, 2, \dots, m \qquad (9)$$

$$S_i^{-} = \sqrt{\sum_{j=1}^{n} \left(y_{ij} - y_j^{-}\right)^2} \qquad i = 1, 2, \dots, m \qquad (10)$$

Step 6: Compute the closeness coefficient C_i^* using Equation (11).

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-} \qquad i = 1, 2, \dots, m;\ 0 \le C_i^* \le 1 \qquad (11)$$

Step 7: Rank the alternatives according to the principle that the alternative with the highest C_i^* value is considered the best.

3. Results and Discussion

Twenty-eight types of copper core conductors provided by a supplier on their website were used to rank the alternatives in this study [10]. Nine criteria describing each alternative were also provided by the supplier. Among them, **C7** and **C9** are classified as cost criteria (type C), while the remaining seven criteria are benefit criteria (type B).

- **C1:** Nominal cross-sectional area (mm²);
- **C2:** Number of strands;
- **C3:** Diameter of copper strand (mm);
- **C4:** Insulation thickness between copper strands (mm);
- **C5:** Sheath thickness (mm);
- **C6:** Overall diameter (mm);
- **C7:** Maximum DC resistance of the conductor at 20°C (Ω/km);
- **C8:** Mass per unit length (kg/m);
- **C9:** Price (thousand VND/m, VNDT = thousand Vietnamese dong).

Table 2 presents the dataset of the 28 copper conductors considered in this study [10].

Table 1: Copper Core Conductor Types [10]

CODE	C1	C2	C3	C4	C5	C6	C7	C8	C9
	B	B	B	B	B	B	C	B	**C**
20225103	1.00	20	0.18	0.6	0.8	5.4	39.00	0.0489	**7.201**
20225106	1.50	30	0.18	0.6	0.8	6.3	26.00	0.0587	11.533
20225107	2.00	40	0.18	0.6	0.8	6.6	19.50	0.0688	18.346
20225108	2.00	32	0.20	0.6	0.8	6.6	19.50	0.0686	26.607
20225110	3.00	48	0.20	0.7	0.8	7.6	13.20	0.0935	42.857
20225111	3.00	30	0.25	0.7	0.8	7.6	13.30	0.0930	24.388
20225114	5.00	50	0.25	0.8	1	9.3	**7.98**	0.1405	38.284
20235103	1.50	20	0.18	0.6	0.8	6.2	39.00	0.0573	57.225
20235106	2.25	30	0.18	0.6	0.8	6.7	26.00	0.0709	23.670
20235107	3.00	40	0.18	0.6	0.8	7	19.50	0.0833	38.418
20235108	3.00	32	0.20	0.6	0.8	7	19.50	0.0830	58.843
20235110	4.50	48	0.20	0.7	0.9	8.3	13.30	0.1187	38.699
20235111	4.50	30	**0.25**	0.7	0.9	8.3	13.30	0.1172	24.412
20235114	7.50	**50**	**0.25**	**0.8**	1.1	10.1	**7.98**	0.1782	35.212
20245103	2.00	20	0.18	0.6	0.8	6.7	39.00	0.0706	26.117
20245106	3.00	30	0.18	0.6	0.8	7.2	26.00	0.0869	36.484
20245107	4.00	40	0.18	0.6	0.9	7.9	19.50	0.1074	54.228
20245108	4.00	32	0.20	0.6	0.9	7.9	19.50	0.1071	26.685
20245110	6.00	48	0.20	0.7	1	9.3	13.30	0.1517	48.426
20245111	6.00	30	0.25	0.7	1	9.3	13.30	0.1507	48.426
20245114	10.00	**50**	0.25	**0.8**	1.1	10.9	**7.98**	0.2200	66.126
20255103	2.50	20	0.18	0.6	0.9	7.7	39.00	0.0830	26.123
20255106	3.75	30	0.18	0.6	0.9	8.2	26.00	0.1075	33.170
20255107	5.00	40	0.18	0.6	0.9	8.9	19.50	0.1294	34.208
20255108	5.00	32	0.20	0.6	0.9	8.9	19.50	0.1298	37.816
20255110	7.50	48	0.20	0.7	1.1	9.7	13.30	0.1871	44.126
20255111	7.50	30	0.25	0.7	1.1	9.7	13.30	0.1858	54.212
20255114	**12.50**	**50**	**0.25**	**0.8**	**1.2**	**11**	13.30	**0.2724**	65.746

Based on the data presented in Table 1, it can be observed that criterion **C1** attains its maximum value for product code **20255114**; **C2** reaches its maximum value for product codes **20235114** and **20255114**; **C3** achieves its maximum value for product codes **20235111**, **20235114**, and **20255114**; **C4** reaches its maximum value for product codes **20235114**, **20245114**, and **20255114**; **C5** and **C6** both attain their maximum values for product code **20255114**.

For the cost criteria, **C7** achieves its minimum value for product codes **20225114**, **20235114**, and **20245114**, while **C8** attains its maximum value of **0.2724**. Meanwhile, **C9** reaches its minimum value for product code **20225103**.

It is evident that no single product simultaneously achieves the optimal values across all nine criteria when compared to the other alternatives. Therefore, the selection process must identify the alternative that is considered the most optimal in a comprehensive sense across all criteria. To accomplish this, it is necessary to determine the weights of the criteria and subsequently rank the product alternatives.

By applying Equations (1)–(4), the weights of the criteria were determined as summarized in Table 2.

Table 2: Weights of the Criteria

C1	C2	C3	C4	C5	C6	C7	C8	C9
0.1089	0.0759	0.1183	0.1675	0.1739	0.1008	0.0804	0.0994	0.0749

After determining the weights of the criteria as presented in Table 2, Equations (5)–(11) were applied to calculate the closeness coefficients CiC_iCi for each product. Based on these values, the alternatives were ranked as illustrated in Figure 1.

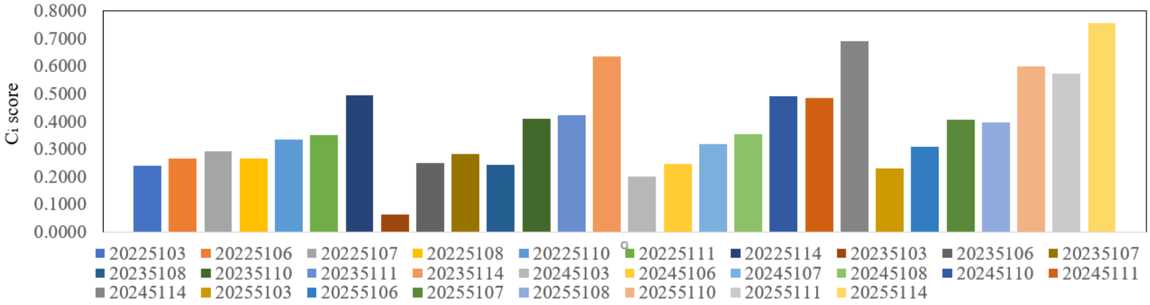

Figure 1: Closeness coefficients CiC_iCi of the product alternatives

As shown in Figure 1, product code 20255114 achieves the highest closeness coefficient with Ci=0.7561C_i = 0.7561Ci=0.7561 among the 28 alternatives. Therefore, this product is identified as the optimal choice.

This conductor has the following specifications: nominal cross-sectional area of 12.50 mm², number of strands 50, strand diameter 0.25 mm, insulation thickness between strands 0.8 mm, sheath thickness 1.2 mm, overall diameter 11 mm, maximum DC resistance at 20°C of 13.30 Ω/km, and mass per unit length of 0.2724 kg/m. The price of this product is 65.746 thousand VND/m.

Conclusion

This study integrates two well-established methods, namely TOPSIS and Entropy, to rank 28 copper core conductor products in order to identify the optimal choice based on nine criteria, including nominal cross-sectional area, number of strands, strand diameter, insulation thickness between strands, sheath thickness, overall diameter, maximum DC resistance of the conductor at 20°C, mass per unit length, and cost.

Among the 28 alternatives, product code **20255114** is identified as the optimal solution. The corresponding values of its parameters are **12.50 mm²**, **50**, **0.25 mm**, **0.8 mm**, **1.2 mm**, **11 mm**, **13.30 Ω/km**, **0.2724 kg/m**, and **65.746 thousand VND/m**, respectively.

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