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Selection of Ideal IoT Based Overhead Conductor for Optimizing the Performance of a Small Hydropower Project

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The selection of a suitable small hydropower project and its criteria for investment is a crucial task involving various aspects and plans. This decision-making can also be seen as a multi-criteria review issue with the correlation of criteria and alternatives. This role should take into account a number of competing aspects due to the growing complexities of social, economic, technical and environmental factors. Traditional decision-making methods cannot address the complexities of such systems. Multi-criteria approaches have more and more versatile tools. The goal of this paper is to assess the applicability of Multiple Criteria Decision-Making (MCDM) based Proximity Index Value (PIV) and Combined Compromise Solution (CoCoSo) technique during the planning and development of small hydropower projects. The application of this PIV novel approach to a small hydropower project organization and expansion scenario is lacking in renewable energy literature due to the difficulty of its evaluation.

Keywords: MCDM, PIV, CoCoSo, Hydropower, Renewable energy.

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1. INTRODUCTION

With the flow of time technology development is on peak. Each and every business tried to adopt and implement advanced technologies within their organization to make to whole process run easier and simple to handle. All these enriched technologies found vast applications in different fields like healthcare, manufacturing, banking, defence etc. At current times it is quite surprising to know that advance technologies even found applications in renewable energy sectors as well. Vast technologies and computational intelligent systems highly contribute in enhancing the sustainability. To promote and establish the smart cities concept, every country should pay attention on the improvement of the energy sector by introducing more advanced and innovative technologies. In this present article, one such type of technological advancement in the field of renewable sector addressing the usage of IoT enable overhead conductors for power transmission serves as the core topic of this present article. Primarily, economic sustainable development to clean the environment by developing the concept of intelligent system grabs the attention of the readers.

According to the record of previous literatures [1,2,3], around 30% of the world's total energy comes from renewable sources. In U.S. almost 12.4% of the total energy consumption has been supplied by renewable sources. There are even some countries that completely depend solely on renewable sources like Iceland whose 75% comes from hydropower and 25% comes from geothermal. With the passing time, most of the countries are mainly focusing on non-traditional sources to enhance sustainability. Even, some countries have adopted renewable concept for domestic uses like lighting homes, offices, schools universities etc. etc. among all the renewable sources, hydropower is the most widely used renewable energy because the producing hydropower is much cheaper compared to other sources. Hydropower is completely eco-friendly and the approximate cost of Rs 2.5/KWH may be incurred for power generation. Some industries include steel plant, health care, oil refining centers may demand a continuous supply of electricity 24 × 7 for non-stop operation[1]. When an organization has to transition from 5-day operations to 7-day operations, the plan may lead to major human relations and organizational challenges if not adequately addressed and obviously strategic decision-making is needed.

As previously discussed, from the aspects of technology and renewable concept, both the things are extremely important. Renewable energy helps to preserve the earth atmosphere and assist in reducing pollution, on the other hand, technologies help to operate the entire system smoothly and better handling. Hence, IoT based overhead conductors for power transmission in a small hydropower projects would be the appropriate topic where both the aspects technology and energy gets merged. Selection of optimum overhead conductor for the electricity transmission is extremely important from the aspect of reducing power loss. During power transmission some of the electricity may get dissipated and some wastage may occur. According to the law of thermodynamics, it is not possible to transmit 100% of the energy produced; obviously some loss will occur. Therefore, selection of appropriate power transmission conductors enabled with high-tech features is much desirable to minimize the loss as much as possible, while increasing the transmission speed. Before selecting the optimum power transmission conductors, various factors need to be considered and examined proper-

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The results were presented at the 3rd International Conference on Innovative Research in Renewable Energy Technologies (IRRET-2023) ly. Additionally, lots of different conductors are also available in the market from different companies, now it's a tough situation for a Decision-Maker (DM) to decide which will be the best conductor option to select from different available alternatives. Thus selection of suitable conductors depends on various factors and alternatives as presented in Table 1.

Under such conflicting circumstances, MCDM is only tool that can provide proper guidance to choose the most optimum one among the available alternatives based on certain conflicting parameters. MCDM deals with certain number of criteria and alternatives; therefore MCDM would be the appropriate approach to analyze the ongoing problem. These conditions serves as a motivation to examine the optimum IoT based power transmission conductors for a mini hydropower plant. The main goal of this artifact is to recommend the superlative IoT conductors amongst five choices based on four properties using the concept of PIV-CoCoSo MCDM system [4,5]. In general, selection of the most feasible alternatives is not an easy task to perform, analysis of multi-objective functions in dimensional space is required. Thus, MCDM is the best fitted tool to examine this type of multiple parameters complex problems [6,7]. These approaches are becoming increasingly important as potential tools for evaluating compound real-world complications due to their integral capacity to assess multiple alternatives on the basis of different parameters for the possible selection of the most appropriate alternatives. These alternatives can be further discussed for their final implementation. These approaches may be used as scientific validation and research techniques for different needs. In addition, they can also be extended to the group decision-making situation as well as the uncertainty analysis [3].

In this paper, selection of optimum overhead conductors for small hydropower project transmission is inspired from Adhikary & Kundu [1]. Previously, similar type of problem was solved by Adhikary & Kundu [1] using MOORA and WPM method based on four selection criteria which are as follows, Thermal Property (TP), Electrical Property (EP), Chemical Property (CP), Mechanical Property (MP). However, after thorough research it has been found that these four factors highly influence the overhead electricity transmission and the magnitude almost remains same as the previous article. Therefore, the present article is updated with IoT enabled conductor selection which was the primary flaw exists in the previous article. The second flaw can be stated as the application of outdated traditional tools like MOORA and WPM which produces inconsistent results and lacks stability. This research intends to fill up the aforementioned research gaps and prescribe more accurate and stable outcomes. The weights are determined using Delphi weighting methods. The criteria weights (wj) as obtained by Adhikary & Kundu [1] are as follows, 0.11 (TP), 0.45 (EP), 0.25 (CP), 0.17 (MP). The overhead conductor selection integrated with IoT enabled function is reanalyzed with the help of two newly developed tools PIV and CoCoSo.

2. MATERIALS AND METHODS

According to Adhikary & Kundu [1], there is no special method by which all minor hydropower transmission and supply lines are planned. Line design components are costly and rely on electrical, mechanical, thermal and chemical parameters of the conductor. Numerous types of transmission conductors are present for distributing electricity, some of them features are, reinforced aluminum alloy (RAC), reinforced aluminum steel (RAS), hard aluminum alloy (HAA), all aluminum alloy (AAA) and all aluminum (AA) conductors. Various variations and modifications of these types of conductors include a wide range of potential designs for conductors. In this selection process, the five types of alternative conductors stated are chosen and the best one is proposed by using PIV and CoCoSo MCDM based on four conflicting criteria. The calculation details are shown elaborately in the upcoming section.

2.1 Proximity Index Value (PIV)

PIV is a newly developed method established by Mufazzal & Muzakkir [8]. It measures the proximity index of the alternatives on the basis of the negative distances from the epitome resolution. Proximity index is definite as the differences of the normalized functions and the best ideal solution of the alternatives. Attributes in relation to the proximity values are applied for evaluating the total PIV value supported by the linear parametric weights. The better alternative can be identified from the normalized interval of the weighted matrix [9,10]. Many researchers have also used Mikowski distances concept to resolve the PIV and TOPSIS [11] data analysis, but robust approach remains unexplored because of its complexity in terms of understandings. Thus, PIV should be considered to be sufficiently accurate [8]. The steps of PIV MCDM as described by the previous researchers are as follows.

Step 1: Alike most of the MCDM problems, PIV also begins with a performance decision matrix having 'm' alternatives and 'n' criteria according to Equation 1 below. The decision matrix is presented in Table 1.

$$D\left(m_i \times n_j\right) = \begin{bmatrix} \mathrm{d}_{11} & \mathrm{d}_{12} & \cdots & \mathrm{d}_{1\mathrm{n}} \\ \mathrm{d}_{21} & \mathrm{d}_{22} & \cdots & \mathrm{d}_{2\mathrm{n}} \\ \dots & \dots & \dots & \dots \\ \mathrm{d}_{\mathrm{m}1} & \mathrm{d}_{\mathrm{m}2} & \cdots & \mathrm{d}_{\mathrm{mn}} \end{bmatrix}, \tag{1}$$

Step 2: Normalized is required to stabilize the data using Equation 2.

$$N_{ij} = \frac{d_{ij}}{\sqrt{\sum_{i=1}^{m} d_{ij}^2}}, \tag{2}$$

Step 3: Each weight of the criteria is multiplied with their respective normalized columns to get the weighted values using Equation 3.

$$W_{ij} = N_{ij} \times w_j, \tag{3}$$

Step 4: Now evaluate the Weighted Proximity Index (WPI) using Equation 4 or Equation 5 according to the nature of the criteria [3]. The U_{ij} is obtained by analyzing the best values of the weighted matrix for each criterion and the normalized weighted values in its range. However, Equation 4 and Equation 5 represents the WPI computations in Table 2.

$$U_{ij} = W_{max}^{j} - W_{ij}\ (for\ beneficial\ criteria), \qquad (4)$$

$$U_{ij} = W_{ij} - W_{min}^{j}(for\ cost\ criteria), \qquad (5)$$

This phase is special to the current proposed process, which helps in eliminating the rank reversal occurrence prior to the previous applied tools WPM and MOORA [3].

Table 1 – Performance matrix

Alternatives	**EP**	**MP**	**TP**	**CP**
RAC	120	60	0.4	5
RAS	125	60	0.4	6
HAA	75	68	0.13	6
AAA	50	50	1	6
AA	45	30	0.6	5
Square sum	40175	15224	1.6969	158
Square root	200.437	123.386	1.303	12.570
Max	125	68	1	6
Min	45	30	0.13	5
Max-Min	80	38	0.87	1

Step 5: In this stage, the Overall Proximity Index (OPI) operation is executed using Equation 6 by summing the WPI values (U_{ij}) conforming to each measure. The WPI values and the OPI of the alternatives are shown in Table 2.

$$OPI_i = \sum_{j=1}^{n} U_{ij}, \qquad (6)$$

According to Mufazzal & Muzakkir [8] this total proximity value encourages the creation of the most stable ranking hierarchy, as it is least influenced by the addition/deletion of alternatives.

Step 6: The alternative with the lowest OPI will reflect the highest proximity with the best possible choice. Lower the value of OPI index, the better is the option. As a result, the alternative with the lowest value of OPI index will be placed in the first position, followed by choices with increasing value of OPI. The ranking of the substitutes is revealed in Table 2.

Table 2 – Computation of WPI and OPI

	EP	**MP**	**TP**	**CP**	**OPI**	**Rank**
RAC	0.011	0.011	0.051	0.020	0.093	2
RAS	0	0.011	0.051	0	0.062	1
HAA	0.112	0	0.074	0	0.186	3
AAA	0.168	0.025	0	0	0.193	4
AA	0.180	0.052	0.034	0.020	0.286	5

2.2 Combined Compromise Solution (CoCoSo)

It was developed by Yazdani et al. [12]. It could be a collection of workable solutions after choosing the options and related criteria. The following steps are validated by Yazdani et al. [12] to elucidate a CoCoSo verdict problem.

Step 1: Formation of a performance evaluation matrix having ‘m’ alternatives and ‘n’ criteria shown by Equation 1 is the first and foremost step for most of the MCDM ranking models. Therefore, CoCoSo also starts with Table 1.

Step 2: The criteria values are normalized according to the criteria nature using a compromise normalization Equation 7.

$$N_{ij} = \begin{cases} \dfrac{d_{ij} - \min\limits_{i} d_{ij}}{\max\limits_{i} d_{ij} - \min\limits_{i} d_{ij}} & \text{for maximum criterion} \\ \dfrac{\max\limits_{i} d_{ij} - d_{ij}}{\max\limits_{i} d_{ij} - \min\limits_{i} d_{ij}} & \text{for minimum criterion} \end{cases}, \qquad (7)$$

Step 3: The sum (S_i) and power (P_i) weight comparability sequence are determined using Equation 8 and Equation 9 respectively.

$$S_i = \sum_{j=1}^{n} w_j N_{ij}, \qquad (8)$$

$$P_i = \sum_{j=1}^{n} N_{ij}^{w_j}, \qquad (9)$$

Step 4: Three evaluation score strategies are used in this step to produce relative weights of other choices, which are obtained using Equation 10 to Equation 12. Decision-makers typically choose $\lambda = 0.5$ in Equation 12 [12].

$$k_{ia} = \frac{P_i + S_i}{\sum_{i=1}^{m} P_i + S_i}, \qquad (10)$$

$$k_{ib} = \frac{S_i}{\min\limits_{i} S_i} + \frac{P_i}{\min\limits_{i} P_i}, \qquad (11)$$

$$k_{ic} = \frac{\lambda S_i + (1-\lambda) P_i}{\lambda \max\limits_{i} S_i + (1-\lambda) \max\limits_{i} P_i}, \qquad (12)$$

Step 5: k_i values are calculated using Equation 13, which determine the final rating. Higher the k_i values, better is the alternative. The alternative ranking has been done according to the increasing values of k_i shown in Table 3.

$$k_i = (k_{ia} k_{ib} k_{ic})^{\frac{1}{3}} + \frac{1}{3}(k_{ia} + k_{ib} + k_{ic}), \qquad (13)$$

Table 3 – Computation of k_{ia}, k_{ib}, k_{ic} and k_i values

Alternatives	**k_{ia}**	**k_{ib}**	**k_{ic}**	**k_i**	**Rank**
RAC	0.213	12.940	0.722	5.882	2
RAS	0.294	18.721	1	8.438	1
HAA	0.202	12.736	0.686	5.750	3
AAA	0.229	11.444	0.778	5.418	4
AA	0.062	2	0.211	1.055	5

3. RESULTS AND DISCUSSION

The PIV and CoCoSo ranking has been proposed accordingly in Table 4. Previously, this problem had been solved by Adhikary & Kundu [1] using MOORA and WPM method and the present ranking has been compared in Table 4 with the previous proposed rankings. From Table 4 it is clear that the outcome rankings of the alternatives are same in all the cases and the present proposed rankings exactly matches with the previous rankings obtained from MOORA and WPM. The present ranking is also portrayed graphically in Fig. 1.

3.1 Validation Using Sensitivity Analysis

On the basis of above computational analysis, a validation needs to be executed to validate the outcome results. Therefore, two types of sensitivity analysis have been conducted to examine the present outcomes.

Single Dimensional Weight (SDW) sensitivity analysis [13] and Weight Replacement Combination (WRC) concept [14, 15] are applied to the ongoing problem. Let us now examine each sensitivity procedure one by one in the following sub-sections.

Table 4 – Ranking comparisons

Alternatives	RAC	RAS	HAA	AAA	AA
MOORA	2	1	3	4	5
WPM	2	1	3	4	5
PIV	2	1	3	4	5
CoCoSo	2	1	3	4	5

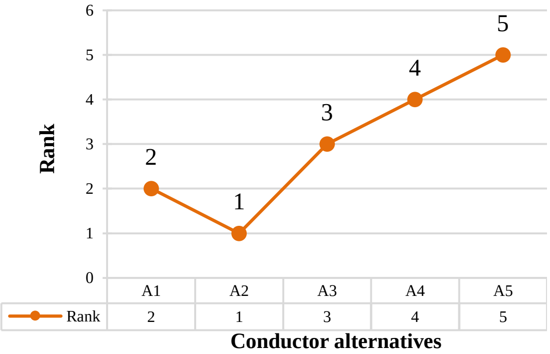


Fig. 1 – Graphical representation of the alternatives ranking

3.1.1 Single dimensional weight sensitivity analysis

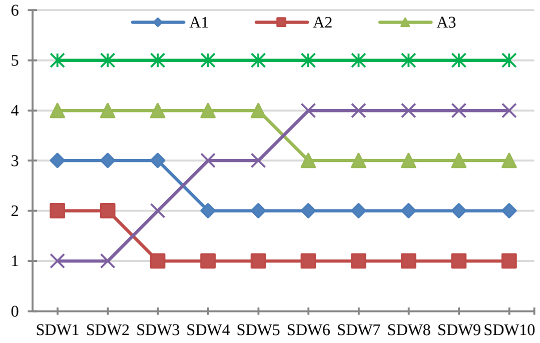
Single dimension deals with the weight variation within a specific range. Maximum potential parametric weight (w_j*) is calculated using Equation 14. The value of w_j* is found to be 0.78. To begin with the analysis, the value of the most important parameter i.e., EP is altered within range $0 \leq w_j^* \leq 0.78$ keeping interval of 0.1, however any interval can be chosen as for example, 0.05, 0.2 etc. etc. the range of the weights variation is shown as 0, 0.1, 0.2, 0.3, 0.4, 0.45, 0.5, 0.6, 0.7, 0.78. Hence, total 10 sets of criteria have been obtained. Now, rests of the weights are adjusted accordingly to maintain the weight constraint rule. The ranking deviations for 10 different sets are also portrayed graphically in Fig. 2 [13,14].

$$w_j^* = [w_{jmax} + (n-1) \times w_{jmin}], \qquad (14)$$

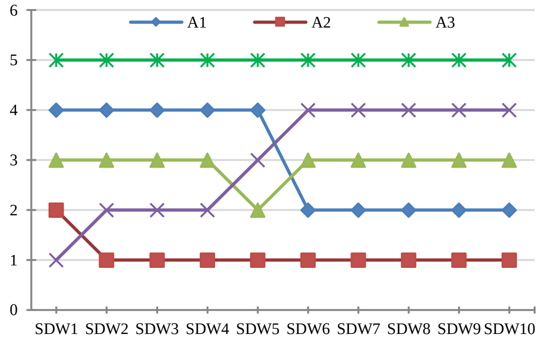
Fig. 2 clearly portrays the ranking variations of the alternatives based on the variation of the highest priority factor weight EP. Both the applied techniques PIV and CoCoSo reacted in a similar way to the weight variation, but CoCoSo somehow outperforms PIV. PIV is more sensitive to the weight variation as can be observed from Fig. 2.

3.1.2. Weight replacement approach sensitivity analysis

This sensitivity analysis is executed using concept of permutation and combination of weights [14]. In this case, four parameters have been considered; therefore there will be 24 different combinations of weights. Applying again the entire 24 newly generated weights combination, ranking has been derived to notice the ranking deviations. The variations in both PIV and CoCoSo are illustrated in Fig. 3 with the help of radar diagrams. From the two radar graphs depicted by Fig. 3 clearly illustrates that CoCoSo is showing more stable results than PIV in this case as well.

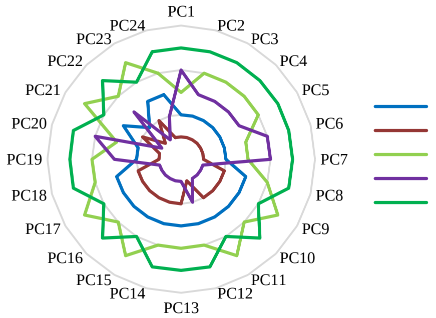


a) PIV

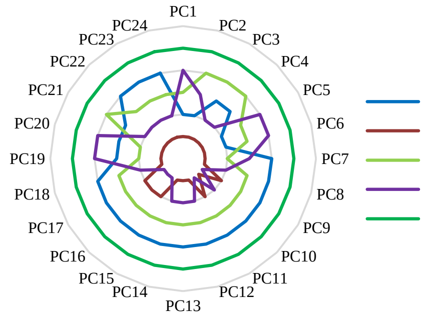


b) CoCoSo

Fig. 2 – Validation using SDW analysis



a) PIV



b) CoCoSo

Fig. 3 – Validation using WRC analysis

4. CONCLUSION

An IoT enabled overhead conductor selection analysis has been presented in this article. Two potential MCDM tools have been applied to produce the precise alternative rating. The key concluding remarks from the overall analysis is that Alternative 2 is the best conductor and Alternative 5 is the worst choice among these 5 available alternatives. It can be seen from the comparison Table 4 that both CoCoSo and PIV are very potential MCDM tools in solving decision making problems and it is giving the exact same ranking as the previous proposed rankings. It is also true that CoCoSo performs well to some extent than PIV in terms of sensitivity, robustness and stability. However, both the methods show similar characteristics while examining a decision issue.

The following issue can be extended in future in many ways. Many other MCDM tools can be implemented to address the following managerial problem. The outcomes from other methods may be compared with the present, and the behavior can also be examined through sensitivity analysis. For solving small hydropower transmission overhead conductor selection problems, there are others factors that can be considered on the basis of different properties to judge the selection process more effectively. Moreover, more number of conductor alternatives can also be added.

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Вибір ідеального повітряного провідника на основі IoT для оптимізації продуктивності проекту малої гідроелектростанції

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Вибір проекту малої гідроенергетики та його критеріїв для інвестування є критичним завданням, що включає різні аспекти та плани. Таке прийняття рішень також можна розглядати як питання багатокритеріального перегляду з кореляцією критеріїв та альтернатив. Ця роль повинна брати до уваги низку конкуруючих аспектів через зростаючу складність технічних і екологічних факторів. Багатокритеріальні підходи мають дедалі більше універсальних інструментів. Метою цієї статті є оцінка застосовності методу прийняття рішень за багатьма критеріями (MCDM) на основі значення індексу близькості (PIV) і комбінованого компромісного рішення (CoCoSo) під час планування та розробки проектів малої гідроенергетики. Застосування цього нового підходу PIV до організації проекту малої гідроелектростанції та сценарію розширення відсутні в літературі з відновлюваної енергетики через складність його оцінки.

Ключові слова: MCDM, PIV, CoCoSo, Гідроенергетика, Відновлювальна енергетика.