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MCDA or MCDM Based Selection of Transmission Line Conductor: Small Hydropower Project Planning and Development

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ABSTRACT
Small hydropower projects are emerging as a solution for sustainable, green, environment friendly, long term and cost-effective source of renewable energy in India for the future. Selecting the appropriate small hydropower project and its parameters in which to invest is a critical task involving different factors and policies. Hence such decision-making can be viewed as a multiple criteria analysis problem with correlating criteria and alternatives. This task should take into consideration several conflicting aspects because of the increasing complexity of the social, technological, environmental, and economic factors. Traditional single criteria decision-making approaches cannot handle the complexity of such systems. Multi criteria methods provide a better and flexible tools. This paper aims to evaluate applicability of multi criteria decision aid to decision makers during the small hydropower project planning and development. To the best of the author's knowledge this novel approach for application of MCDA or MCDM to small hydropower project planning and development scenario is absent in renewable energy literatures due to its assessment complexity.
KEYWORDS: small hydropower; MCDA; MCDM; renewable energy; water resources

I. INTRODUCTION

The total installed power generating capacity in India during March 2012 was reported as 2, 02,979.03 MW out of which only 19.24% i.e. 39,060.40 MW is thru hydro power. The identified small hydro power potential sites are 14300 MW (approx) and installed are 2150 MW (approx.) till date. The cost of clean-green-friendly small hydroelectricity is relatively low i.e. Rs2.5/KWH (approx.), compared to others and thus making it a competitive source of renewable energy as demonstrated [1, 2]. Some industries, like oil refining, health care and power generation have (24x7) type continuous schedules almost from the day they start. When a company needs to move from 5-day operations to 7-day operations, the strategy can result in significant human relations and operational problems if not handled properly and needs critical decision makings.

Small hydropower projects (i.e. up to 25MW in India) are much more advantageous than conventional medium or large hydropower projects. Small hydropower plant requires very less flow or head compared to conventional hydropower plants. Reservoir is also not required for small hydropower projects as they are mostly run-of-river type. Environmental and social impacts of small hydropower projects are also negligible compared to conventional medium or large hydropower projects [3, 4]. In small hydropower generation "Water-the white coal" is used non-destructively by the force of gravity, which is a totally carbon-free and inexhaustible resource to generate power. Hence there is no consumable fuel or raw material inventory required. Naturally flowing rivers and streams, flow towards lesser elevation and thus provide suitable site for small hydropower generation. The water used in hydro power generation remains fully intact and utilizable or reusable afterwards [5, 6]. In general, evaluating small hydropower project is a complex analysis that can be defined as a multi-dimensional space of different indicators and objectives. Hence the use of multi-criteria decision analysis (MCDA) or multi-criteria decision making (MCDM) or multi-criteria analysis (MCA) techniques provides a reliable methodology to rank alternatives in the presence of different objectives and limitations [7, 8]. Even with the large number of available MCDA methods, none of them is considered the best for all kinds of decision-making situations. Different methods often produce similar as well as different results even when applied to the same problem using same data. There is no better or worse method but only a technique that fits better in a certain situation. These methods are gaining importance as potential tools for analyzing complex real-world problems due to their inherent ability to judge different alternatives on various criteria for possible selection of best / suitable alternatives. These alternatives may be further explored in depth for their final implementation. These methods can be used as empirical validation and testing tools of various needs. In addition they can be also applied to group decision making scenario as well as for uncertainty analysis. A review of various published literatures on sustainable energy planning indicates greater applicability of MCDA methods in changed socio-economic scenario. The methods have been very widely used to take care of multiple, conflicting criteria to arrive at better solutions. Increasing popularity and applicability of these methods beyond 1990 indicate a paradigm shift in renewable energy planning, development and policy analysis. More research is still to be done to explore the applicability and potentiality of more MCDA methods to real-world planning and designing problems to reduce the gap between theory and practice. Many soft-wares (1000Minds, D-Sight etc.) have also been developed to facilitate such analysis or study. This paper on small hydropower project planning and development based on multi criteria decision making is an effort in that direction.

II. MATERIALS AND METHODS

There is no unique process by which all small hydropower project transmission and distribution lines are designed. All major cost components of line design depend upon the conductor's electrical, mechanical, thermal and chemical parameters. The major types of overhead conductors used for electrical transmission and distribution are: All Aluminum Conductor (AAC); All Aluminum Alloy Conductor (AAAC); Aluminum Conductor Steel Reinforced (ACSR); Aluminum Conductor Aluminum Alloy Reinforced (ACAR) etc. The various combinations and modifications of these conductor types provide a wide variety of possible conductor designs.

The selection of the optimum conductor type and size for a given line consists of finding that conductor which results in the lowest cost spread over the life of the line. The transmission line design engineer is confronted with choosing a conductor type from among this bewildering assortment. This choice must be based on basic conductor parameters. Hence the decision making processes are complex, as small hydropower generation is more challenging today. Most people, when confronted with such problems, will attempt to use intuitive or heuristic approaches to simplify the complexity until the problem seems more manageable. In the process, important information may be lost, opposing points of view may be discarded, and elements of uncertainty may be ignored. Hence there is a need for simple, systematic, and logical methods or mathematical tools to guide decision makers in considering a number of selection attributes and their interrelations. Thus, efforts need to be extended to identify those attributes and to eliminate unsuitable alternatives, and to select the most appropriate alternative using simple and logical methods. MCDA or MCDM method is a process of evaluating real world situations, based on various qualitative or quantitative criteria in certain, uncertain or risky environments to suggest an alternative, course of action, strategy and policy among the available options. MCDA method not only provides better-supported techniques for the comparison of product or project alternatives based on decision matrices but also has the added ability of being able to provide structured methods for the incorporation of project stake holder's opinions into the ranking of alternatives [9, 10]. A systematic methodology to combine quantitative and qualitative inputs from scientific studies of those criterions to rank small hydropower project alternatives has yet to be fully developed. Hence, decision makers often do not optimally use all available and necessary information in choosing between identified project or equipment alternatives.

Any MCDA or MCDM problem usually includes four main stages: alternative formulation and criteria selection, criteria weighting, evaluation and final treatment and aggregation. The preliminary step in MCDA or MCDM method is to formulate the alternatives for sustainable energy DM problem from a set of selected criteria and to normalize the original data of criteria. The purpose of normalization is to obtain dimensionless values of different criteria so that all of them can be compared. Secondly, criteria weights are determined to show the relative importance of criteria in MCDA method. Then, the acceptable alternatives are ranked by MCDA methods with criteria weights. Finally, the alternatives' ranking is ordered. If all alternatives' ranking orders in different MCDA methods are just the same, the decision making process is ended. Otherwise, the ranking results are aggregated again and the best scheme is selected.

The attributes are of two types, beneficial (i.e. higher values are desired) and non-beneficial (i.e. lower values are desired). A quantitative or qualitative value or its range may be assigned to each identified attribute as a limiting value or threshold value for its acceptance. It is not absolute that more and more criteria are helpful to the conductor selection decision-making. Likewise, less-criteria are beneficial to the evaluation of SHP systems. Popular criterion selection methods are Delphi Method, Least Mean Square (LMS) Method etc. All criteria or factors have their internal impact reclassified to a common scale. Weight is assigned to the criteria to indicate its relative importance. Different weights influence directly the results or ranking. Consequently, it is necessary to obtain the rationality and veracity of criteria weights. Three factors are usually considered to obtain the weights: the variance degree of criteria, the independency of criteria and the subjective preference of the decision-makers. Popular weighting methods are Equal Weights Methods, Subjective Weighting Methods (Delphi Method, AHP etc.), Objective Weighting Methods (LMS Method, TOPSIS etc.) and Combined Weighting Methods. Then it is the turn to determine the preference orders of alternative after determining the criteria weights so that MCDA or MCDM Methods are employed to get the ranking order.

Popular MCDA or MCDM methods are divided into three categories: Elementary Methods, Unique Synthesizing Criteria Methods and Outranking Methods. For Water resource or renewable energy project MCDA or MCDM methods are divided into four categories: Distance Based Method (TOPSIS, VIKOR etc.), Outranking Method (ELECTRE, PROMETHEE etc.), Priority or Utility Based Method (Weighted Average Method, AHP etc.) and Mixed Category (EXPROM-2, STOPROM-2 etc.) [11, 12].

Usually, the decision maker selects the best alternative based on the ranking orders after the calculation in a selected MCDA method. However, the creditability of a process is necessarily verified so that the results of the ranking orders are computed by a few other MCDA methods sometimes. The application of various MCDA methods of calculation may yield different results. Therefore, the ranking results are necessarily aggregated again and the best scheme from the alternatives is selected. The methods used to aggregate the preference orders are called as aggregation methods (Voting Method, Mathematical Aggregation Method etc.).

This paper introduces MCDA methods that can be used in small hydropower project scenario showing its application in planning and development. They are also applicable for small hydropower project management or policy analysis scenario. This paper clearly demonstrates the potentiality, applicability and simplicity of Priority or Utility Based Method: MOORA (Multi Objective Optimization on the Basis of Ratio Analysis) for initial ranking and WPM (Weighted Product Method) for its validation thus providing multi-criteria decision aid to decision makers during the small hydropower project – planning, development and management. These methods are widely used in any renewable energy as well as water resources project or policy - planning, development and management. Hence it is applied to small hydropower project scenario successfully as shown.

The Multi Attribute Utility Theory (MAUT / MAVT, SMART etc.) is not very extensively used in renewable energy or water resource project such as small hydropower project scenario. This may be due to requirements of interactive decision environment required in formulating utility functions, complexity of computing scaling constants using the algorithm.

Conventional weighting methods are not recommended for the projects requiring social and environmental impact analysis for its approval such as small hydropower projects. Delphi Weighting Method is very popular in these cases. It is a semi-structured communication method, developed as a systematic, interactive forecasting method which relies on engineers, managers or experts. In the standard method, the experts answer the queries in two or more phase. After each phase, a facilitator provides an anonymous summary of the experts' detailed forecasts report. Thus, experts are encouraged to revise their earlier answers in light of the replies of other members of their panel. During this process the range of the answers will decrease and the group will converge towards the "correct" solution. Finally, the process is stopped after a pre-defined stop criterion. The mean or median scores of the final phase or rounds determine the final results. Delphi is based on the principle that decisions from a structured group of individuals are more accurate than those from unstructured groups and has been mentioned as "collective intelligence". The technique can also be adapted for use in meeting individuals and is then termed as mini-Delphi. The main objective of "Delphi Method" was to combine expert opinions on likelihood and expected development time, of the particular technology, in a single indicator. The weights obtained for conductor selection are: 0.47, 0.17, 0.11 and 0.25.

III. THEORY AND CALCULATIONS

MOORA: Multi Objective Optimization on the Basis of Ratio Analysis method is a widely used approach in renewable energy as well as water resource project scenario. The method starts with a decision matrix of different alternatives to different objectives. Then the matrix is normalized. The next step is to calculate the composite score. If there is a criterion co-efficient for each alternative then calculate the weighted composite score as:

$$y_i = \sum_{j=1}^{g} w_j x_{ij}^* - \sum_{j=g+1}^{n} w_j x_{ij}^*$$

Finally rank the alternatives in descending order.

WPM: Weighted Product Method is the simplest and most commonly used approach in sustainable energy systems. The composite or overall score of an alternative is calculated as:

$$S_i = \prod_{j=1}^{n} x_{ij}^{w_j}, \quad i = 1, 2, \ldots, m$$

Then the resulting composite or overall scores for each alternative can be used to rank, screen, or choose an alternative. The best alternative is the one whose score is the maximum.

IV. RESULT AND DISCUSSION

The rankings are not significantly affected by the choice of the MCDA or MCDM methods employed. Here the transmission line conductor selection criteria are: Electrical property (F1), Mechanical property (F2), Thermal property (F3) and Chemical property (F4). Let A1 to A5 are the various alternatives of conductors.

Table-1: Decision Matrix

Decision Matrix				
	F1	F2	F3	F4
A1	120.000	60.000	0.400	5.000
A2	125.000	60.000	0.400	6.000
A3	75.000	68.000	0.130	6.000
A4	50.000	50.000	1.000	6.000
A5	45.000	30.000	0.600	5.000

Table-2: Weighted Normalized Matrix

Weighted Normalized Decision Matrix				
	F1	F2	F3	F4
A1	0.281	0.080	0.036	0.099
A2	0.293	0.080	0.036	0.118
A3	0.176	0.091	0.012	0.118
A4	0.117	0.067	0.090	0.118
A5	0.105	0.040	0.054	0.099

Exact commercial data are not publicly accessible, but given are generated data based on provided relations between various parameters which are very close to an actual small hydropower project data. It is observed that all these methods are quite capable to deal with both the cardinal or ordinal data and can provide the total ranking of the considered alternatives, although they have different mathematical treatments and operational approaches.

Table-3: MCDA Rank (MOORA)

Weighted Composite Score		
MOORA Method - RANK		
A1	0.424	2
A2	0.455	1
A3	0.373	3
A4	0.259	4
A5	0.218	5

Table-4: MCDA Rank Validation (WPM)

Overall Score		
WPM Method - RANK		
A1	0.483	2
A2	0.515	1
A3	0.363	3
A4	0.362	4
A5	0.285	5

Here all methods give ranking order as A2-A1-A3-A4-A5. Moreover, the sensitivity analyses have been proved that all methods have provided very similar and stable rankings. Given the subjectivity of decision maker judgment, these results are satisfactory. So basically, all these MCDA methods whether they adopt preference function or weighted sum utility value, indicate how much an alternative is preferred to other alternatives. The minor discrepancy that may appear between the intermediate rankings obtained by different methods can be attributed to the difference in their mathematical and operational approaches to select the best alternative, the way of dealing with criteria weights in their calculations and introduction of additional parameters affecting the final ranking of the alternatives. In few cases where strong disagreement between these methods may occur, it is due to presence of mixed ordinal-cardinal data in the decision matrix. Thus, the focus would lie not on the selection of the most appropriate preference ranking method to be adopted, but on proper structuring of the decision problem considering relevant criteria and decision alternatives.

V. CONCLUSION

Evaluating and selecting small hydropower project alternative is a complex analysis that can be defined as a multi-dimensional space of different indicators and objectives. The use of MCDM or MCDA techniques provides a reliable methodology to rank alternative renewable energy or water resources such as small hydropower products and projects in the presence of different objectives and limitations. Even with the large number of available MCDA methods, none of them is considered the best for all kinds of decision-making situations. Different methods often produce similar or different results even when applied to the same problem using same data due to various modelling methods. There is no better or worse method but only a technique that fits better in a certain situation. Thus, it can be said that although the mathematical and operational procedures of the considered preference ranking methods substantially differ from each other, but there are similarities in the concepts they use to reach the final evaluation and ranking of the alternatives in terms of overall utility or significance or preference rating.

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The authors declare that there is no conflict of interests.

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