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MULTI-DIMENSIONAL FEASIBILITY ANALYSIS OF SMALL HYDROPOWER PROJECT IN INDIA: A CASE STUDY

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ABSTRACT

The assessment of Small Hydro Power (SHP) sites for project planning and development represents a relatively high proportion of overall cost. A high level of experience and expertise is required to accurately conduct this multi-dimensional assessment at both pre-feasibility and feasibility analysis stage. A variety of multi-criteria decision analysis or making (MCDA or MCDM) methods as well as computer-based feasibility assessment tools have been developed for the same. However, a reliable assessment implies physical site surveying and planning at pre-feasibility stage itself. The advent of Geographic Information System (GIS) along with these feasibility analysis software tools has been of enormous use for the feasibility analysis of SHP project at minimum time-cost-effort for making further decision. To the best of the author's knowledge this software tool based novel approach for Indian small hydropower project feasibility analysis is absent in renewable energy literatures due to its assessment complexity.

Keywords: hydropower, RET screen, feasibility analysis, MCDA, MCDM.

1. INTRODUCTION

Indian Government has taken up certain resolutions towards the promotion of Small Hydro Power (SHP) projects keeping in mind the various advantages. Grants have been allotted and also provided subsidies to promote alternative sources of electricity in the country. On 24th May 2003, Honourable Prime Minister of India launched a scheme, formulated by Central Electricity Authority (CEA) for the preparation of Preliminary Feasibility Report (PFR) of 162 new hydropower schemes totalling to over 50, 000 MW. National average annual per capita consumption is 603 units whereas in Bihar it is 75 units as published in report of FY: 2005-2006. The National Electricity Policy (NEP) aims to achieve an annual average per capita consumption of 1, 000 units after 2012. Small hydropower generation [1, 2] as a clean, renewable and long-term source of energy with peaking capability has a valuable role in this power generation addition strategy for Bihar and can significantly supplement the large coal-based capacity addition targets for the state. Once established, small hydropower plants have long and productive lives in excess of 35 years, and in the long-run have substantively cheaper operating costs than coal-based or natural gas based plants. Bihar has been making rapid progress in harnessing its small hydro. Despite bifurcation of state, and transfer of potentially attractive small hydro locations on geographic boundaries, Bihar State Hydroelectric Power Corporation Ltd. (BHPC) has expanded its generation capacity from 18.3 MW in 2000 to 47.1 MW till the end of the 10th Plan period. The cost [3, 4] of clean-green-friendly hydroelectricity in India is approx. Rs2.5/kWh (i.e., US$55/MWh approx. FY: 2006) which is relatively low, compared to others and thus competitive.

2. LITERATURE REVIEW

Over the last few decades, a variety of multi-criteria decision analysis or making (MCDA or MCDM) methods [3, 5] on renewable energy project planning and management or policy assessment as well as computer-based feasibility analysis or decision support system (DSS) tools have been developed to address this problem and enable prospective developers to make a multi-dimensional assessment of the techno-economic feasibility of a SHP project before any huge investments. A MCDA method must be selected and applied to the problem under consideration in order to rank alternatives. The data and the degree of uncertainty are key factors for the decision-maker when selecting among several MCDA or MCDM methods. The preliminary step in MCDA or MCDM method is to formulate the alternatives for sustainable energy decision making 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 or MCDM method. Then, the acceptable alternatives are ranked by MCDA or MCDM method with criteria weights. Finally, the alternatives' ranking is ordered. If all alternative ranks order in different MCDA or MCDM 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 SHP project feasibility decision-making. 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. Weights are then assigned to the criteria to indicate its relative importance. Popular weighting methods are Equal Weights Methods, Subjective

Weighting Methods (Delphi Method, AHP etc.) [6, 7], 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 (Weighted Sum Method, Weighted Product Method etc.), Unique Synthesizing Criteria Methods (AHP, TOPSIS etc.) and Outranking Methods (ELECTRE, PROMETHEE etc.) [8, 9]. Usually, the decision maker selects the best alternative based on the ranking orders after the calculation in a selected MCDA method. The application of various MCDA or MCDM method 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 (E.g. - Voting Method, Mathematical Aggregation Method etc.). MCDA or MCDM problems also have two broad classifications: Multiple Objective Decision Making (MODM) and Multiple Attribute Decision Making (MADM) or Multi Criteria Analysis (MCA). The multiple-objective decision making model (e.g. Global criterion method, Utility function method etc.) is appropriate for "well-structured" problems. Well-structured problems are those in which the present state and the desired future state (objectives) are known as the way to achieve the desired state. The model encompasses an infinite or very large number of alternative solutions that are not explicitly known in the beginning, constraints are analyzed, and the best solution is reached by solving the mathematical model. Multiple-attribute decision making or multi-criteria analysis model (TOPSIS, ELECTRE etc.) is appropriate for "ill-structured" problems. Ill-structured problems are those with very complex objectives, often vaguely formulated, with many uncertainties, while the nature of the observed problem gradually changes during the process of problem solving. The weak structure makes it impossible to obtain a unique solution. The ambiguity originates from the structure of goals or objectives, which is complex and is expressed in different quantitative and qualitative measurement units. Results of ill-structured problems are different dimensions criteria for the evaluation of solutions and variable constraints. The model encompasses a finite number of alternative solutions that are known at the beginning. The problem is solved by finding the best alternative or a set of good alternatives in relation to defined attributes or criteria and their weights. Another way of MCDA or MCDM method classification for water resource system planning and management problems includes: Distance Based Method (Compromise Programming, TOPSIS etc.), Outranking Method (ELECTRE, PROMETHEE etc.), Priority or Utility Based Method (Weighted Average Method, AHP etc.) and Mixed Category (EXPROM-2, STOPROM-2 etc.).

Similarly, various software tools [10] and interactive maps or atlases are deployed publicly on the Web and indicate the locations of SHP sites and their main features as shown in Table-1. The main aim of these software tools (E.g. - RETScreen, IMP 5.0, Hydro Help etc.) is to find a rapid and reasonably accurate means of predicting the techno-economic output of a particular small hydropower project scheme from flow duration curve (FDC) or flood frequency analysis (FFA).

Table-1. Features of various SHP project feasibility analysis software's.

Name	Application	Features							
		Hydrology	Power & Energy	Costing	Economic Evaluation	Preliminary Design	Hybrid Simulation	MCD Optimization	Control Strategy
IMP	International	X	X						
RETScreen	International	X	X	X	X				
Peach	International	X	X	X	X	X			
HydroHelp	International	X	X	X	X	X			
Green Kenue	International	X							
Homer	International	X					X	X	X
iHoga	International	X					X	X	X
Matlab	International	X					X	X	X

3. MATERIALS AND METHODS

RETScreen software [11, 12] is capable of assessing all types of renewable energy technologies (RETs) viability factors such as energy resources available at the project site, equipment performance, initial project costs, periodic project costs, financing, income (or savings), environmental characteristics of energy displaced, environmental credits etc. Worldwide meteorological data incorporated in the software includes both the ground-based meteorological data and NASA's satellite-derived meteorological data sets. The RETScreen's hydroelectric model can be used anywhere in the world. The same has been used for the feasibility analysis of a 6MW capacity SHP site of BHPC in India as discussed in this paper.

4. RESULT AND DISCUSSIONS

The proposed site is located on the banks of tributary "Baghla Dhar", and has comparatively a small catchment area (as "Baghla Dhar" is not the major path of "Kosi River") at Supaul district in Bihar. Considering the above parameters, we analyzed the annual rainfall data of the local area (since the major inflow in the river is due to rainfall upstream). The geographical co-ordinates of the proposed 6MW BHPC-SHP project site as shown in Figure-1 are as under:

Latitude- 26°09´ North

Longitude- 86°53´ East

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Figure-1. Location map of 6MW (BHPC) SHP site.

The application of this tool for the proposed SHP case study will also demonstrate its capacity to perform feasibility studies across the world, for various design options and financing as well as different economic scenarios. Six worksheets are provided in the small hydropower project RETScreen file:

Start
Energy Model
Cost Analysis
GHG Emission Analysis (Optional)
Financial Analysis
Sensitivity Analysis and Risk Analysis (Optional)

a) Start

The "Start" worksheet of the RET-Screen software has basic information's about the project, planner, type of project, site location etc as shown in Figure-2.

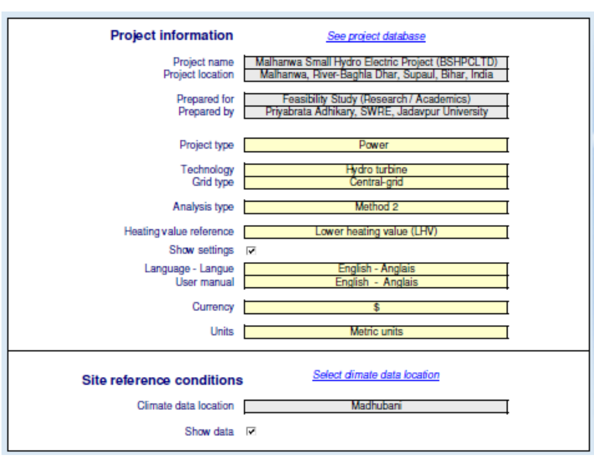

Figure-2. RETScreen - start worksheet (SHP Project Analysis).

b) Energy model

"Hydrology Analysis" is the first step, referred to as the "Energy Model", and requires the user to collect basic information concerning the site conditions: latitude and longitude, available head, flow, or drop in elevation. RETScreen calculates the estimated renewable energy delivered for SHP projects, based on the adjusted available flow (adjusted flow-duration curve), the design flow, the residual flow, the load (load-duration curve), the gross head and the efficiencies or losses. The flow-duration curve of 6MW SHP site has been calculated and shown in Figure-3.

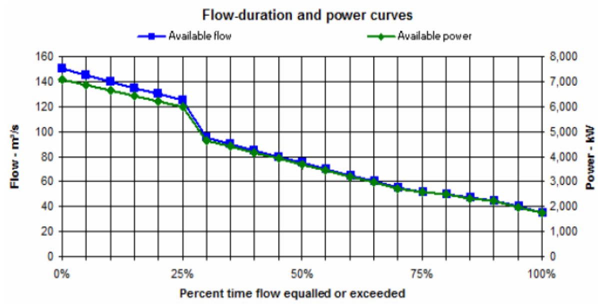

Figure-3. RETScreen - flow duration curve (Energy Model).

Combined turbine performance is also calculated as shown in Figure-4 at regular intervals on the flow-duration curve. Plant capacity is then calculated and the power-duration curve is established. Available energy is simply calculated by integrating the power-duration curve. In the case of a central-grid, the energy delivered is equal to the energy available.

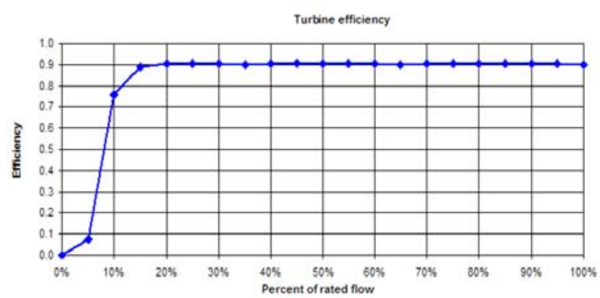

Figure-4. RETScreen - combined turbine efficiency curve (Energy Model).

c) Cost analysis

During the "Cost Analysis", a detailed cost analysis is performed taking into account initial costs and annual costs (maintenance, insurances etc.) involved in the project as shown in Figure-5. The total initial cost calculated was INR 51.00 Crores i.e., US$ 11, 333, 333 (Year: 2006). The cost of "Feasibility Study", "Development" and "Engineering" is 3% to 5% each of "Total Initial Cost". The cost of "Power System" is 30% to 35% whereas "Balance Item and Misc. Cost" is 50% to 55% of it. "O and M Cost" is generally 10% to 15% of the "Total Initial Cost" for SHP plant.

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Project costs and savings/income summary			
Initial costs			
Feasibility study	3.5%	$	397,121
Development	4.2%	$	473,110
Engineering	4.4%	$	498,102
Power system	35.1%	$	3,979,000
Balance of system & misc.	52.8%	$	5,986,000
Total initial costs	**100.0%**	**$**	**11,333,333**
Annual costs and debt payments			
O&M		$	170,000
Fuel cost - proposed case		$	0
Debt payments - 10 yrs		$	1,291,113
Total annual costs		**$**	**1,461,113**
Periodic costs (credits)			
User-defined - 10 yrs		$	100,000
Annual savings and income			
Fuel cost - base case		$	0
Electricity export income		$	1,880,421
Total annual savings and income		**$**	**1,880,421**

Figure-5. RETScreen - cost analysis.

d) Emission analysis

The RETScreen has the capacity to estimate the amount of green house gases (GHG), which could be avoided as a result of using renewable energy sources such as SHP project to reduce carbon foot print. The required input data is the fuel type used. The net annual GHG emission reduction tCO_2 is 31892 for the 6MW SHP site as evident from Figure-6.

GHG emission reduction summary	Base case GHG emission tCO2	Proposed case GHG emission tCO2			Gross annual GHG emission reduction tCO2	GHG credits transaction fee %	Net annual GHG emission reduction tCO2
Power project	34,665.2	2,773.2			31,891.9		31,891.9
Net annual GHG emission reduction	31,892	tCO2	is equivalent to	5,841	Cars & light trucks not used		

Figure-6. RETScreen - emission analysis.

e) Financial analysis

A number of different economic and financial feasibility indices were calculated such as the year-to-positive cash flow, Internal Rate of Return (IRR) and Net Present Value (NPV) as shown in Figure-7. The RETscreen calculations are based on 17.6% pre-tax IRR equity and 6.8% after-tax IRR assets. It shows a simple payback over 7years and equity payback over 9years for the 6MW SHP project of BHPC.

Financial viability		
Pre-tax IRR - equity	%	17.6%
Pre-tax IRR - assets	%	6.8%
After-tax IRR - equity	%	17.6%
After-tax IRR - assets	%	6.8%
Simple payback	yr	6.6
Equity payback	yr	8.9
Net Present Value (NPV)	$	3,982,883
Annual life cycle savings	$/yr	412,984
Benefit-Cost (B-C) ratio		2.17
Debt service coverage		1.30
Energy production cost	$/MWh	43.04
GHG reduction cost	$/tCO2	(14)

Figure-7. RETScreen - financial analysis.

The RETscreen accumulated cash flow results over 35 years of operation is shown in Figure-8. The net present value (NPV) calculated is $3, 982, 883 and the benefit-cost (B-C) ratio is 2.17 which is more than unity, hence the project is feasible for the standard SHP based electricity export rate of INR 2.5/kWH (US$55/MWH).

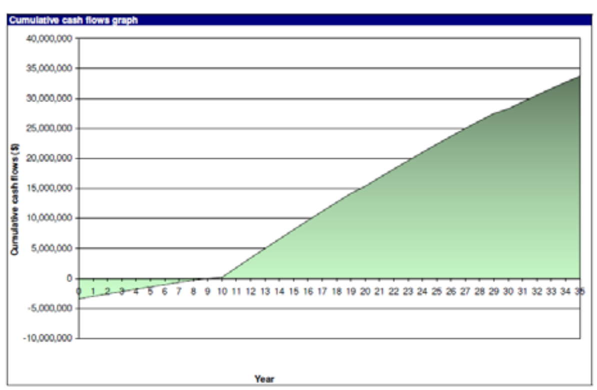

Figure-8. RETScreen - cumulative cash flow (Graphical Analysis).

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f) Sensitivity analysis and risk analysis

Different economic scenarios were studied in order to indicate the viability of the installation, by varying the electricity price (EP) and the CPI (Consumer Price Index). CPI affects the annual cost of the plant (insurance, staff and maintenance). The electricity price is fixed every year according to economic and political parameters. Assuming that the plant has a lifetime of 35 years, the minimum EP increment was calculated in order to offset the increased fixed costs incurred by the CPI. The electricity price was adjusted in accordance with the annual fixed tariff referred to as the CPI, with or without governmental subvention. Thus from sensitivity and risk analysis the SHP project feasibility is re-assured.

5. CONCLUSIONS

Small hydropower projects offer great opportunities for sustainable development of the countries. Being the cheapest, domestic, and renewable resource of energy, it deserves to be high up on the government's investment agenda. It is also a great market that creates business opportunities for private companies, especially in the developing countries like India. RETScreen Clean Energy Project Analysis Software is a decision support system (DSS) tool developed in order to assist the planners and decision makers in developing the renewable energy or any energy efficient projects. The software can be utilized worldwide and it reduces time-cost-effort spent while identifying and assessing potential energy projects and alternatives at the feasibility or planning stage. The software makes it a lot easier to observe the effects of the techno-economic changes in the project formulation. It can be concluded that the decision maker may benefit (in terms of time-cost-manpower etc.) from the analysis results of RETScreen software in evaluating various alternatives of the hydropower project if he or she is already informed about the few weaknesses of the software (ignore problems of earthquake, erosion, sediment etc.).

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