Indian SHP Project Planning And Development : A Review Of Decision Support System Tools

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Abstract

This paper review and compare software tools for the planning and design of small hydropower projects (SHP) applicable especially for Indian scenario. The main emphasis is on small scale hydropower resource assessment computer tools and methodologies corresponding to a preliminary or pre-feasibility study level in India. The reviewed tools vary from simple initial estimates to quite sophisticated software. The integration of assessment tools into Geographic Information System (GIS) environments has helped in the strengthening of the evaluation of the water power potential in the case of the spatial variability of different factors affecting it. However, a reliable assessment of real SHP feasibility implies some physical site surveying also, but this traditional assessment can be greatly facilitated using GIS techniques in India. To the best of the author's knowledge such review paper on Indian SHP project decision support system tools is absent in renewable energy literatures due to its assessment complexity.

Keywords: Hydropower, RETScreen, Homer, GIS, MCDA

1. Introduction

Over the last several decades, a variety of computer-based assessment tools have been developed world wide to address this problem and enable a prospective developer to make an initial assessment of the techno - economic feasibility of a project before spending substantial sums of money. A high level of experience and expertise is required to accurately conduct SHP site assessment. Tools those are applicable for Indian scenario, ranges from simple first estimates to quite sophisticated programs. However, a reliable assessment of techno - economically feasible potential implies some physical site surveying also. The decision-making process **[1, 2]** regarding the choice of hydro based renewable energy sources for energy supply is multidimensional, made up of a number of aspects at different levels – economic, technical, environmental, and social. Thus the advent of Geographic Information System (GIS) software has been of enormous use as a way of capturing the range of information required, which is discussed further in this paper. Some decision support system (DSS) or multi-criteria decision analysis or making methods (MCDA or MCDM) as MAUT, AHP etc **[3, 4]** are intended to select the best choice from a given set of renewable energy technology (RET) alternatives. Other DSS methods as ELECTRE, PROMETHEE etc **[5, 6]** are based on the idea of developing a partial order, useful for sorting out large lists of alternatives down to a short list among which the decision maker can select. The main aim of these software tools is to find a rapid and reasonably accurate means of predicting the energy output of a particular hydro scheme. These predictions involve establishing the "head" and the "flow duration" data **[7, 8]** that give the time variability of water discharge sufficiently accurately for capacity sizing of the plants. Needless to say, the accuracy of hydrological analysis is crucial for the cost effectiveness of a hydro scheme. In India, hilly stream catchments were considered for the assessment of hydropower potential using spatial tool GIS and a hydrological model. Prospective sites for SHP development were determined using remote sensing data. The application of GIS to the site selection of a small run-of-river hydropower project by considering engineering, economic and environmental criteria and the social impact was also employed. The main aim of this study was to review publicly available software tools and interactive Web-based maps designated for SHP site identification, with the assessment corresponding to levels from reconnaissance up to pre-feasibility studies.

2. Materials and Methods

In common practice, a virtual size limit is fixed for small hydropower plants. It is usually determined by installed capacity and varies greatly from a few kilowatts to 10MW in India. Computer software's designated for SHP project assessment can be integrated with or without GIS. Only the latest computer-based packages have integrated GIS tools or vice versa. To assess river flow, there are two main approaches: the flow duration curve (FDC) and the simulated stream-flow (model) methods or flood frequency analysis (FFA). Computer programs intended for modelling hydro-mechanical equipment (for instance, turbines), such as Computational Fluid Dynamics (CFD); civil, geotechnical and other relevant hydropower engineering; and project cost issues including detailed design studies, are considered beyond the scope of this paper and are not discussed.

In general, for the application of GIS for assessing hydropower potential, several typical components can be identified [9, 10]:

Step-1: Gathering of river basin hydrological characteristics and associated attribute information as spatial GIS data and later using them for broad-based analysis;

Step-2: Development of a DEM for the river basin using a variety of primary sources as input data for GIS database development and for later use in the hydropower potential evaluation;

Step-3: Development of SHP assessment tools as specialized GIS extensions and integrating them into GIS systems;

Step-4: Performance of SHP evaluation, feasibility study and presentation of the results by GIS tools

Internationally applicable software's that can also be used for Indian SHP planning and designing are briefly discussed below:

IMP 5.0: This is a convenient tool for evaluating small-scale hydroelectric power sites. By utilizing Integrated Method for Power (IMP) combined with the relevant meteorological and topographical data, in approximately one day of in-house study, an experienced user can evaluate all aspects of an un-gauged hydro site. This includes a power study, development of a flood frequency curve and fish habitat analysis. It is useful to non-specialists exploring possibilities for small hydro development and for consulting engineers who need preliminary estimates of flood frequency and energy potential. IMP consists of: Flood Frequency Analysis Model, Watershed Model, Hydroelectric Power Simulation Model, Fish Habitat Analysis Model. It is applicable for India as well as other countries.

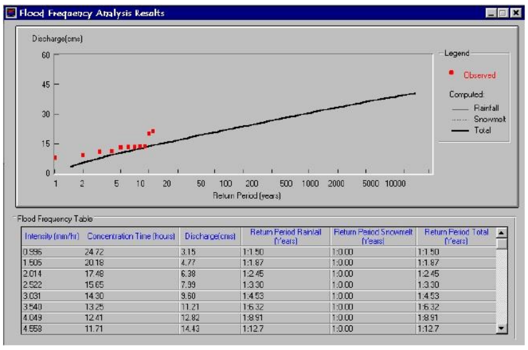

Figure1: IMP 5.0 Software – FFA

RETScreen: This is a Microsoft Office, Excel based unique decision support tool developed with the contribution of numerous experts from government, industry, and academia. The software, provided free-of-charge, can be used world wide to evaluate the energy production and savings, costs, emission reductions, financial viability and risk for various types of Renewable-energy and Energy-efficient Technologies (RETs). The software also includes product, project, hydrology and climate databases, a detailed online user manual, and case studies. The RETScreen Small Hydro Project Model software can be used world-wide to easily evaluate central-grid, isolated-grid and off-grid hydro projects of any SHP size. It is applicable for India as well as other countries.

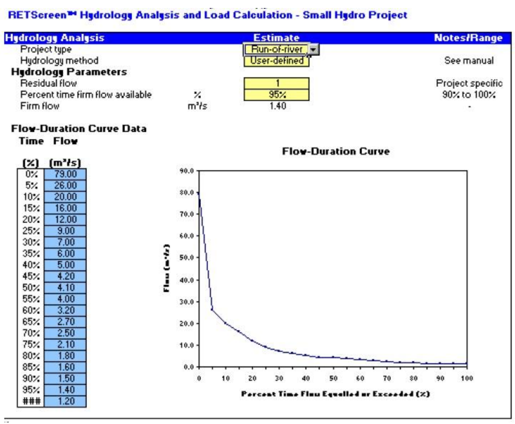

Figure2: RETScreen Software – FDC

PEACH 2.0: This is a sophisticated program and is offered for SHP planning and designing across the world. The program is designed to take a developer through all the necessary procedures in

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designing, building and commissioning a small hydro scheme and analyzing the financial returns which may be expected. It follows following steps: Site Data Definition, Project Creation, Project Design, Plant Design, Economic and Financial Analysis, Report. The output provides following details: Site, Project and Design parameter set definition; Power curve and main results; Construction costs; Bill of quantities; Cost flows - Yearly cash flow; Economic analysis - Economic analysis graphic results; Financial analysis - Financial analysis graphic results. It is applicable for India as well as other countries.

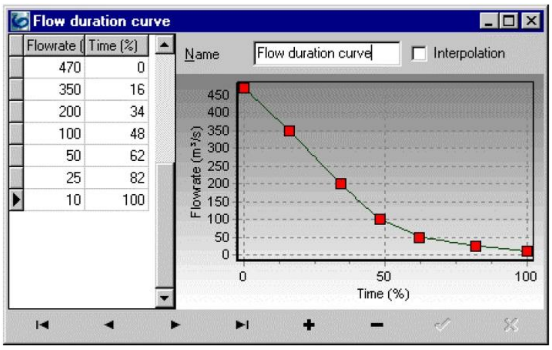

Figure3: PEACH 2.0 Software – FDC

HydroHelp 1.2: Microsoft Office, Excel based HydroHelp series of programs has been developed to allow engineers to obtain an initial assessment of a hydro-electric site, with a minimum of site data. The programs are intended for use by relatively inexperienced hydro engineers, by providing an "expert guide" throughout the project design process. The programs do not include any hydrologic or financial analysis. There are presently 4 programs in the series, all for developments with surface power plants:

- HydroHelp 1.2 for turbine selection.
- HydroHelp 2.2 for Francis turbine project.
- HydroHelp 3.2 for Impulse turbine project.
- HydroHelp 4.2 for Kaplan turbine project.

The user starts with program #1 which provides the user with the best turbine suitable for the flow, head and number of units desired in the power plant. Selection is based on more than simple suitability. The user then proceeds to the next program, #2 for Francis turbines, #3 for impulse turbines or #4 for Kaplan turbines, based on the type of unit selected in the first program. These programs guide the user through the design process as to the options available and the best choice. It is applicable for India as well as other countries.

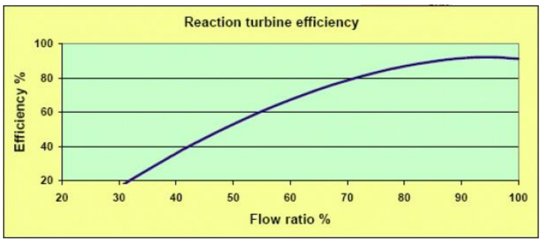

Figure4: HydroHelp1.2 Software

Green Kenue: This is an advanced hydrological toolkit within a GIS-enabled modeling environment and software package. The software package provides an integrated numerical modeling environment for hydrological models and 1D hydraulics and routing models. Green Kenue is based on the core Kenue, which provides one unique and shared platform and look-and-feel for purposes ranging from the development of advanced cross-field modeling environments to the design of tailored technical decision support systems. This software can provide engineering firms with advanced tools for more precise hydrologic estimates needed to design small hydro sites. It is applicable for India as well as other countries.

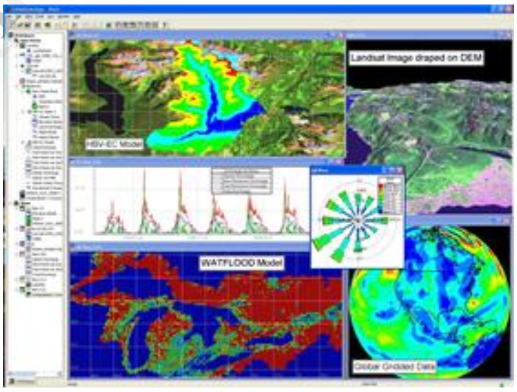

Figure5: Green Kenue Software

HOMER: It is a computer model that assists in the design of micro-power systems and facilitates the comparison of power generation technologies across a wide range of applications. HOMER models a power system's physical behavior and its lifecycle cost, which is the total cost of installing and operating the system over its life span. HOMER allows the designer to compare many different RET design options based on their technical and economic merits. It also assists in understanding and quantifying the effects of uncertainty or changes in the inputs. HOMER can model off-grid and grid connected micro-power systems serving electric and thermal loads, and comprising any RET combination. It is applicable for India as well as other countries.

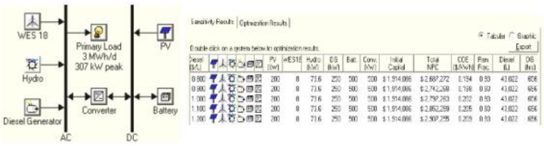

Figure6: HOMER Software

iHOGA: iHOGA (improved Hybrid Optimization by Genetic Algorithms) is software developed in C++ for the simulation and optimization of Hybrid Renewable Systems including SHP for generation of electrical energy (DC and/or AC). Optimization is achieved by minimizing total system costs throughout the whole of its useful lifespan, when those costs are referred to or updated for the initial investment (Net Present Cost, NPC). Optimization is therefore financial (mono-objective). However, the program allows for multi-objective optimization, where additional variables may also be minimized: equivalent CO2 emissions or unmet load (energy not served), as selected by the user. Since all of these variables (cost, emissions, or unmet load) are mutually counterproductive in many cases, more than one solution is offered by the program, when multi-objective optimization for RET is sought. Some of these solutions show better performances when applied to emissions or unmet load, whereas other solutions are best suited for costs. It is applicable for India as well as other countries.

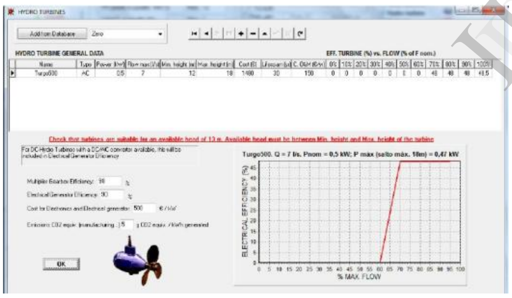

Figure7: iHOGA Software

MATLAB: Setting up and solving a large optimization problem for portfolio optimization, constrained data fitting, parameter estimation, or other applications can be a challenging task. As a result, it is common to first set up and solve a smaller, simpler version of the problem and then scale up to the large-scale problem. Working with a smaller version reduces the time that it takes to identify key relationships in the model, makes the model easier to debug, and enables you to identify an efficient solution that can be used for the large-scale problem. Three techniques for finding a control strategy for optimal operation of a hydroelectric dam: using a nonlinear optimization algorithm, a nonlinear optimization algorithm with derivative functions, and quadratic programming can be achieved thru MATLAB. It is applicable for India as well as other countries.

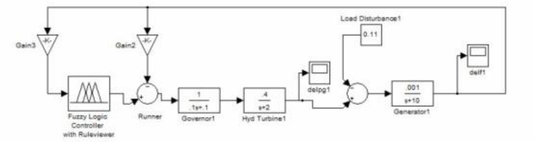

Figure8: MATLAB Software.

3. Results and Discussion

To assess river flow, there are two main approaches: the flow duration curve (FDC) and the simulated stream-flow (model) methods or flood frequency analysis (FFA) [11, 12]. A less accurate intermediate approach is based on the mean annual flow (MAF), which can also be used in some programs. With recent advances in GIS technology and the increased availability of high-quality topographic and hydrologic data, it is now possible to rapidly assess power potential on a widespread basis while maintaining a relatively high level of detail. In most countries, GIS data are free of charge.

Table 1: SHP planning and development - decision support system tools for Indian Scenario

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

For hydropower project studies, remote sensing (e.g., LIDAR), which is becoming cost effective compared with conventional surveying, has represented a leap forward in producing digital elevation models, especially in areas that are difficult to access. Using Digital Elevation Model (DEM) [13] and regional hydrologic data, these software tools are able to calculate the amount of hydropower available on all streams in a study area, screening out sites within environmentally sensitive or excluded areas, and to estimate project costs. It is absolutely clear that a reliable assessment of real SHP site feasibility implies some physical site surveying, but this traditional assessment can be greatly facilitated with computer programs if the GIS technique [14, 15] involving the spatial variability of catchments characteristics is integrated.

4. Conclusion

During the last 15-20 years, hydropower assessment tools based on computer software have improved considerably, accounting particularly for the complex integration of river catchments attributes world wide. This improvement is due mainly to the advent of GIS. The increased availability of high-quality topographic and hydrologic data, it is now possible to rapidly assess power potential on a widespread basis while maintaining a relatively high level of detail. In most countries, GIS data are free of charge. For hydropower project studies, remote sensing is becoming cost effective compared with conventional surveying, has represented a leap forward in producing digital elevation models, especially in areas that are difficult to access. Using DEM and regional hydrologic data, these software tools are able to calculate the amount of hydropower available on all streams in a study area, screening out sites within environmentally sensitive or excluded areas, and to estimate project costs. It is absolutely clear that a reliable assessment of real SHP site feasibility implies physical site surveying, but this traditional assessment can be greatly facilitated with computer programs if the GIS technique involving the spatial variability of catchments characteristics is integrated in India.

5. Acknowledgement

The authors declare that there is no conflict of interests.

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