Development of TRIDEnT (Tidal Resource Investigation, Device, & Energy Tool) as a Rapid Evaluation System for Tidal In-Stream Energy Resource Assessment, Power Estimation, Energy Projection, and Technology Matching

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Abstract

A Matlab-based rapid evaluation software called Tidal Resource Investigation, Device, and Energy Tool (TRIDEnT) was developed. TRIDEnT aims to serve as a useful tool for tidal energy resource assessment for selected Philippine coastal waters. With this tool, the user can easily evaluate potential sites where turbine-based power generators could be installed. At the backend lies extensive simulation runs performed using DELFT3D model developed by Deltares which is a sophisticated hydrodynamic model used to study water velocities and other physico-chemical conditions. Based from these simulation data, the program returns the theoretical power the could be extracted at the user-specified area and time frame. Moreover, other valuable data can be provided by the program such as the water velocity within a region as well as how often it reaches a particular threshold value. Such information gives the user the ability to evaluate and compare multiple sites at the same time which is particularly useful during site-feasibility assessment stages. Lastly, the software was constructed in such a way that sophisticated optimization algorithms can be easily incorporated which would allow real-time optimization of parameters given certain criteria and constraints set by the user.

Keywords

tidal energy, rapid evaluation, resource assessment, site suitability, technology matching, optimization tool

1. INTRODUCTION

The Ocean Renewable Energy (ORE) industry is presently picking up [1]. To date, only the tidal barrage has reached commercial maturity and is being used in the U.K.[2]. Thermal and Salinity gradient technologies have not reached the pre-commercial maturity level. Ocean thermal energy conversion (OTEC) technologies are still very expensive and the lack of pilot sites with installed power systems harnessing this type of energy pulled away support from some investors worldwide. Wave energy conversion (WEC) and tidal in-stream energy conversion (TISEC) systems have reached full-scale and are in the pre-commercial scales of maturity [2].

1.1 Tidal In-Stream Energy Evaluation

Technologies for harvesting energy from tidal currents are being developed worldwide (see Fig. 1). Some of these technologies are already undergoing sea trials [1], [2]. Given that the tidal energy resource is more predictable than wave energy resource, it is better to investigate the potential of harnessing the tidal resource at this stage for the Philippines.

Fig.1 Tidal Current Conversion Technologies [1], [2]
(a) SeaGen™ (b) Kobold™ (c) Clean Current™

A number of methodologies and tools are already available for sufficient resource assessment of tidal energy potential. Although already useful, there is a need for an integrated, flexible rapid evaluation tool for tidal in-stream energy assessment which considers: resource, technology, cost, power, availability, and other relevant criteria for a holistic decision support system for potential sites.

Table 1. Comparative Review of Representative Tidal Energy Evaluation Tools and TRIDEnT

	EPRI	ESRU	STEM	TRIDEnT
Tides	wxTide / NOAA	EasyTide	Total Tide	Flexible (e.g. OTIS/MSI Dataset)
Currents	Surface + 1/10 power law	Fluid Equations (Excel)	MSPF & MNPF + Formzahl #	DELFT3D
Flow	Total Average flow: 2D	Regional flow:2D	Total Average flow: 1D	3D
Bathymetry Considered	Transect Outline only	Admiralty chart: roughness and dimensions	NO	**YES**
Sites	USA	Sound of Islay	Multiple	**Multiple**
TISEC Device(s)	8 devices reviewed, RA with SeaGen	3 types: VA, HA, and oscillating HF	15 reviewed, RA with: Neptune Proteus III	**Flexible database**
Capture Area	Trapezoidal method	Location-dependent; 30m limit,5m buffer from surface/seabed	variable	variable
Significant Impact Factor	considered	considered	Not considered	considered
Energy	Annual	Annual	Annual	**Flexible**
Economics	Included	Not included	included	included
Cost of Electricity	Included	Not included	included	included
Decision Support System	No	No	No	**YES**
Comprehensive Map	No	No	No	**YES**
Platform	Multiple	AutoCAD, Matlab, Excel	Excel	Matlab

1.2 Review of TISE Evaluation Tools

Crucial to power development plans are the information and tools for assessing generation by various types of power plants. If tidal power is to be included in the roster of possible power generation types, it is important to have handy tools that produce dynamic estimates with spatial and temporal reliability to better guide those who want to pursue resource surveys, feasibility studies, optimization, environmental impact assessments, and a number of other research in the field.

Table 1 shows a component-wise relative comparison of some tidal energy evaluation methods and tools benchmarked with TRIDEnT.

The Electric Power Research Institute (EPRI) of the U.S.A. has made a study on the techno-economic viability of Tidal In-Stream Energy in North America[3].The Energy Systems Research Unit (ESRU) of the University of Strathclyde includes a general technology matching effort to test the variation in power output depending on the type and size of the TISEC device to be installed[4]. Hardisty[5] uses an Excel-based resource assessment tool called the Simplified Tidal Economic Model (STEM).

2. METHODOLOGY

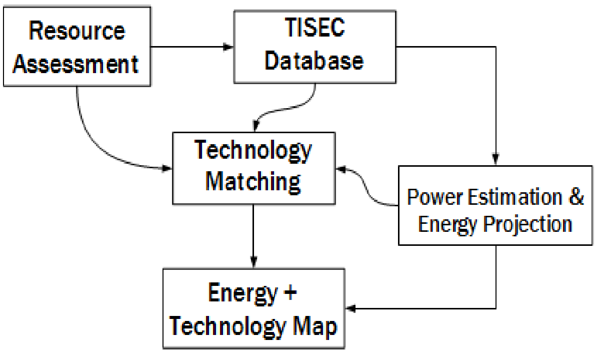


Fig. 2 General Framework for a Tidal Energy Rapid Evaluation Tool

The block diagram above shows the general framework that TRIDEnT was based. For each site of interest, an assessment of the tidal in-stream resource is done. The velocity data is then be transformed into power estimates through the use of the power equation applicable for a specific tidal in-stream energy conversion (TISEC) device. Energy output is projected for that site using that chosen TISEC device. Since different TISEC devices have different characteristics, such as cut-in speed, rated power, cost, etc.., the devices in the TISEC database are "matched" with the resource of the site by means of a selected criteria which involves cost, power output (capacity factor), and availability. We will do these steps for a number of sites and produce maps that contain the energy potential of the site, the matched technologies for the site with their corresponding cost, capacity, availability, and estimated cost of electricity.

TRIDEnT is designed to:
(1) integrate resource assessment information,
(2) produce velocity histograms,
(3) store a database of TISEC devices,
(4) calculate power and energy estimates.

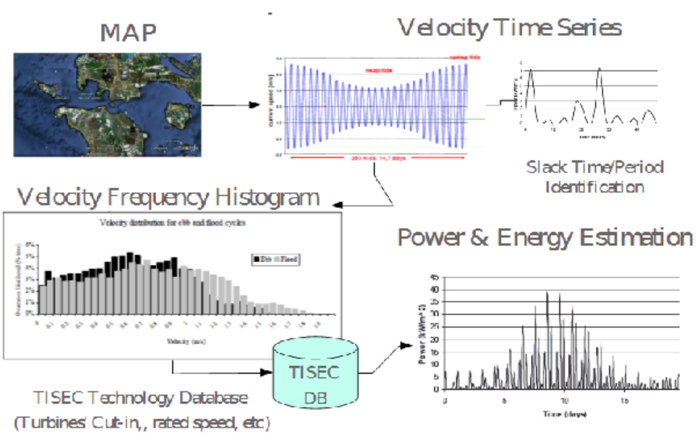


Fig. 3 Design of TRIDEnT's Process Flow

TRIDEnT is developed using Matlab as prototyping platform. It may be ported to Excel or some other simpler user platforms later on. Matlab was chosen as the development platform primarily because of the software's ability to handle and process matrices of data which will be at the core of tidal energy resource assessment. Also, the GIS and CFD tools used can export data to Matlab-readable formats thus making it a very good hub for interfacing DELFT3D Simulations, ArcGIS maps, Teledyne ADCP Data, and the TISEC device database.

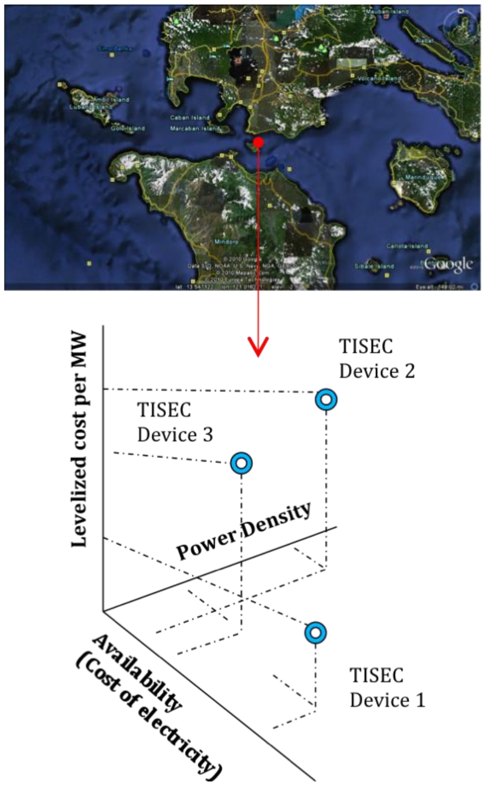
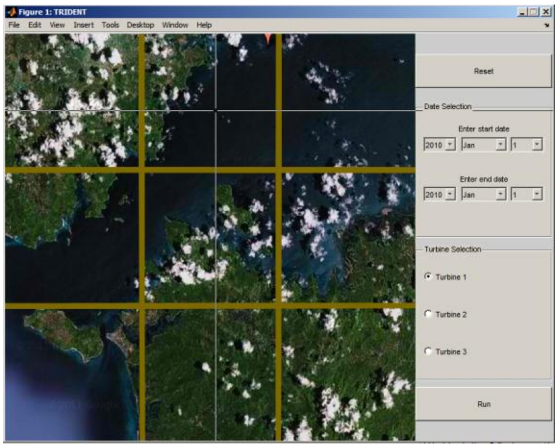


Fig. 4 Decision Support System of TRIDEnT

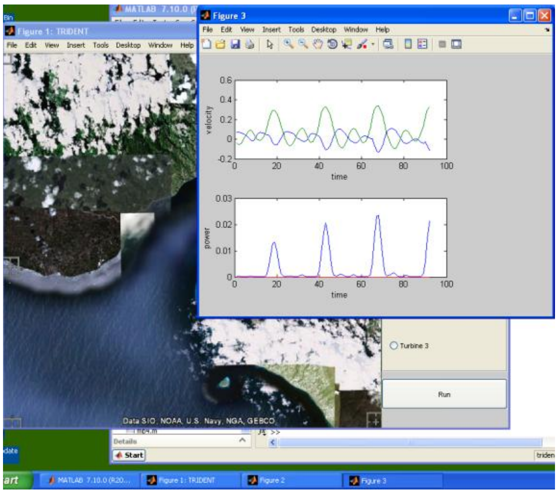
Once we are able to gain a good handle on the current velocity profiles for multiple sites, we can easily choose from existing TISEC devices by employing a simple criterion or a set of criteria (e.g. maximum power output, minimal slack time, maximum energy output, rated speeds, etc..) and can easily decide which TISEC device/s would be suitable for a specific location in a given site. It may be that a site with a certain channel would yield maximum energy if a farm of TISEC devices are installed, and not necessarily of the same kind.

2. RESULTS

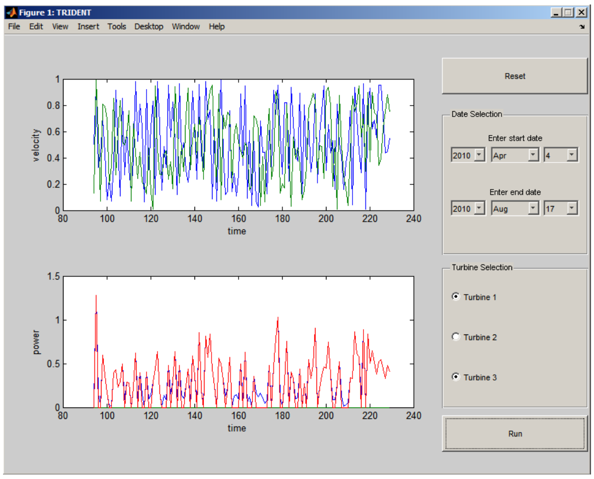
Fig. 5 shows a series of screen shots from TRIDEnT.



(a)



(b)



(c)

Fig. 5 TRIDEnT Screen Shots
(a) Map / Area Selection Screen
(b) Time Series: Depth-Ave Velocity and Power
(c) Multiple Turbine Power Output

3. CONCLUSION

A prototype of a simple rapid evaluation system for tidal in-stream energy was designed. TRIDEnT can be used in resource assessment of sites, power estimation and energy projection of TISEC devices for specified sites, and in assisting stakeholders for the matching of energy extraction technologies for sites of interest.

Even though TRIDEnT is still at the early stages of development, a huge need is addressed by the subsequent versions which may prove to be quite a substantial contribution in the ocean renewable energy industry not only in the Philippines, but also for other nations in South East Asia.

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