Wave resource assessment and site selection for the ShoreSWEC

James R Joubert
Johannes L van Niekerk
Department of Mechanical & Mechatronic Engineering
Stellenbosch University

Centre for Renewable and Sustainable Energy Studies

Abstract

The ShoreSWEC represents a single arm of the original Stellenbosch Wave Energy Converter or SWEC that is build into a breakwater or harbour wall. In this study the available wave energy resource along the southwest coast of South Africa was modelled to identify possible areas with sufficient wave power for the deployment of the device. A set of site selection criteria was developed and used to evaluate 20 possible sites identified along the coast. The most important criteria was to determine if there is a new (caisson) breakwater planned at a particular site or if an existing breakwater will be extended in the future. Furthermore the new or existing breakwater must be orientated obliquely to the dominant wave direction to ensure that the ShoreSWEC chambers operate sequentially. The result of the evaluation procedure initially identified 5 possible sites and after further refinement Granger Bay, adjacent to Cape Town's V&A Waterfront, was selected as the most suitable site. A wave energy resource assessment was conducted for the Granger Bay site and the design of the ShoreSWEC for this location is currently underway.

1 Introduction

During the oil crisis in the 1970's the industry sponsored Ocean Energy Research Group (OERG) led by Prof Deon Retief of Stellenbosch University designed and developed the Stellenbosch Wave energy Converter (SWEC) for the prevailing wave conditions off South Africa's west coast.

The SWEC consists of a pair of submerged collectors (arms) coupled in a V-formation to a conventional air turbine and generator mounted above the water level in a tower at the apex of the V. Each collector arm is made up of 12 oscillating water column (OWC) chambers in which the water level oscillations displaces air via inlet and outlet valves to low and high pressure manifold systems which drives an air-turbine and generator to convert the wave energy into electricity.

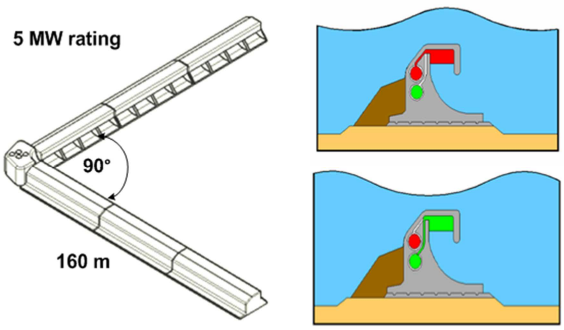

Figure 1: Layout of the SWEC and its operational principle

This is a nearshore system reducing the transmission distance and consequent high cost of underwater transmission cabling. The SWEC is founded on the seabed which provides a fixed reference frame that enhances survivability and efficiency as well as eliminates the need for complex mooring configurations (refer to Figure 1 for a schematic layout of the SWEC), (Joubert, 2009). Unfortunately a full scale SWEC device was never constructed in the ocean due to the high capital cost required for such a project and the difficulty of obtaining the required permissions and permits for the construction of a stand-alone wave energy device, something that has not been done before in South Africa. In order to overcome these barriers an adaption of the SWEC, called the ShoreSWEC, was recently patented by Stellenbosch University.

The ShoreSWEC (refer to Figure 2) is a rectifying OWC wave energy converter integrated into a caisson breakwater structure. Integrating wave energy converters (WECs) in (new or existing) coastal structures has the main advantage of sharing cost between the breakwater and the WEC in addition to the advantages over “normal” breakwaters where the loads and wave heights in front of the device are reduced as the wave energy is absorbed and not reflected (Martins et al, 2005). The ShoreSWEC needs to be orientated at an oblique angle to the dominant wave direction to ensure that the chambers operate sequentially as each wave moves along the length of the device.

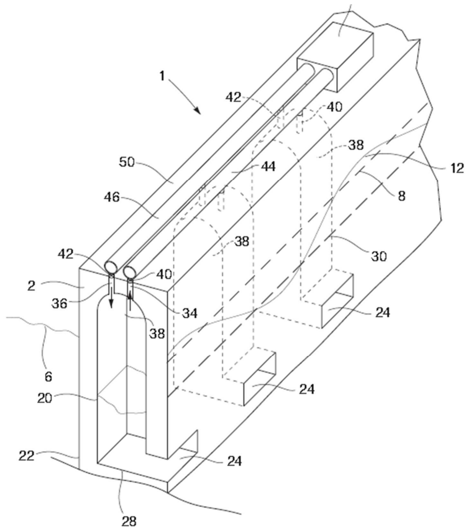

Figure 2: Part-cross sectional view of the ShoreSWEC

The ShoreSWEC comprises of a series of OWC chambers in a breakwater founded on the seabed and extends above the still water level. Wave induced water level oscillations force air into and out of the chamber via unidirectional valves located in the roof of the chamber. The valves are connected to high and low pressure conduits which run along the length of the roof of the device. The conduits form a closed circuit pump system which drives a unidirectional air-turbine at the far end of the device (Joubert, 2009). Studies are currently underway to optimise the design parameters (length, orientation, size of openings etc.) of the ShoreSWEC by means of numerical and experimental models.

In order to identify locations best suited for the deployment of a ShoreSWEC prototype a set of site selection criteria was developed and used to evaluate potential sites along the South African coast. In this paper the site selection criteria are discussed and the findings of the investigation are presented. Some conclusions are made and the way forward discussed.

2 Site selection investigation

2.1 Site selection criteria

Twenty sites along the South African coasts were evaluated using the following criteria, ranked according to importance, to determine a suitable site for the ShoreSWEC:

2.1.1 Existing and/or new breakwater structure with suitable orientation

Sites were only considered if it had an existing (preferably caisson) breakwater or a new breakwater planned orientated at an oblique angle to the dominant angle of wave attack. The water depth at the site is also an important consideration due to the fact that caisson breakwaters are typically deployed in water depth greater than that of the breaker zone to avoid the high impact loads of breaking waves. Therefore, the water depth of a potential site must be 10 m or greater to be beyond the breaker zone for the dominant wave conditions on the south-western coast.

2.1.2 Wave energy resource characteristics

The available wave energy resource at a particular location is of primary importance and determines the generation capacity of a deployed prototype, directly impacting on the economic feasibility of the project. The wave energy resource at the shoreline, where the ShoreSWEC is to be deployed, is significantly lower than offshore and therefore the device must be long enough to ensure that it has sufficient generation capacity. A suitable location for device deployment must preferably have sufficient wave energy available throughout the year with low variability and manageable energy peaks during extreme storm events. The coastal zones with the greatest wave energy resource are therefore not necessarily the most ideally suited for wave energy conversion due to the design and cost penalty associated with the maximum storm energy that a prototype will have to survive. Sites were evaluated according to its nearshore wave energy resource, due to the fact that most recorded and modelled wave data available for this study represents nearshore wave energy conditions. Sites were only considered if it had a nearshore mean annual average wave power resource ranging from at least 20 to 45 kW/m crest length.

2.1.3 Impact on the surrounding environment and regulatory requirements

The necessary permission and permits for power generation and land use for the prototype will only be granted if the Environmental Impact Assessment (EIA) finds that the deployed device will not adversely impact the surrounding environment such as ecologically sensitive areas, commercial shipping routes and fishing grounds. The device is less likely to have negative impacts on the surrounding environment if it is deployed in an existing coastal development such as port with approved EIA's in place.

2.1.4 Potential power purchaser

The ShoreSWEC prototype must be deployed in close proximity to a populated coastal region ensuring a market for the generated power. Generating power locally from a renewable energy source could greatly benefit small coastal communities or densely populated coastal cities such as Cape Town, Port Elizabeth, East London, Durban and Richards Bay. Wave energy conversion can potentially be an economically viable alternative to fossil fuel electricity generation currently used for South Africa's island settlements of Robben Island, Gough Islands and Marion Island.

2.1.5 Service vessels and waterfront infrastructure for system deployment, retrieval and servicing

Deploying, retrieving and servicing the ShoreSWEC prototype will require service vessels and coastal infrastructure such as tugs and cranes. Most of these services and infrastructure are found at all the mayor ports, making the proximity to the nearest port an important consideration.

2.1.6 Proximity to device fabrication, assembly facilities and expertise

The ShoreSWEC prototype will be manufactured from prefabricated steel reinforced concrete units and to reduce transport costs the prototype must be deployed in close proximity to a manufacturing facility. The caissons units will most likely be cast in-situ and floated out to their final position.

2.1.7 Proximity to onshore grid interconnection points

The loads, capacities and availability of the coastal utility grid were considered when selecting suitable sites.

The above mentioned site selection criteria were used to evaluate 20 potential sites off the South Africa coast of which 5 was considered for further investigation. The 5 most promising sites included: Saldanha, Koeberg, Granger Bay, Hermanus and Coega. From these five sites Granger Bay was identified as the most promising location, mainly due to the fact that in the past a development was planned here that would require a caisson breakwater perfectly orientated to accommodate the incorporation of the ShoreSWEC.

2.2 Granger Bay

The Granger Bay site is situated adjacent to the Port of Cape Town (refer to Figure 3 below) ensuring accessibility to the extensive port infrastructure and services available. The modified caisson units that the ShoreSWEC comprise of can be cast in the port's Sturrock dry dock and floated into position. The planned development is not expected to greatly impact the sea traffic entering the port of Cape Town, but it is still important to determine the amount of wave reflection especially resulting from waves with a dominant wave direction of north to northwest. Electricity generated by the ShoreSWEC can be directly used by the V&A Waterfront, Port of Cape Town or the City of Cape Town. In order to determine the generation capacity of a ShoreSWEC prototype at Granger Bay the available wave energy was quantified by means of a resource assessment. The methodology and findings of which are discussed in the following section.

Figure 3: Aerial view of Granger Bay - potential site for the ShoreSWEC

3 Table Bay wave energy resource assessment

In order to determine the available wave energy resource at Granger Bay statistical parameters of the spatial distribution of wave power in Table Bay was derived by numerically simulating 10 years of hindcast wave data from offshore to inside Table Bay using the SWAN wave model (Booij et al 2009). Refer to (Joubert, 2008:113) for a detailed description of the wave energy resource assessment methodology used. An example of the model output is shown below in Figure 4 depicting the mean annual average distribution of wave power in Table Bay over an 11 year period. Figure 4 shows that the Granger Bay site (indicated by the star) is quite sheltered from the dominant wave conditions due to the shadow effect of Mouille Point. The site is ideally situated to achieve one of the main objectives of the ShoreSWEC which is to demonstrate the WEC technology while ensuring the survivability of the device.

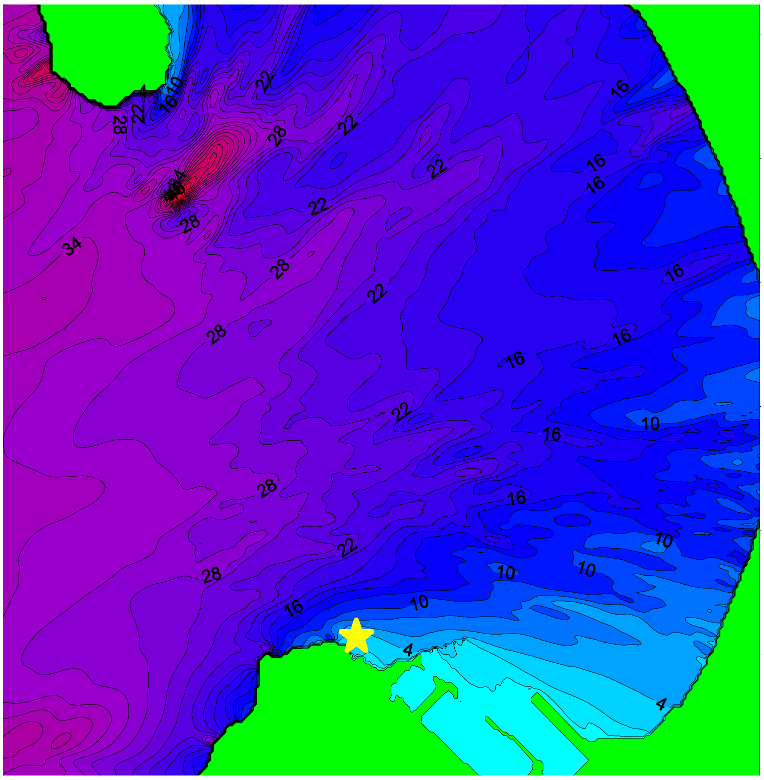

Figure 4: Mean annual average wave power distribution of Table Bay based on more than 10 years of hindcast wave data.

Output from the model developed for this study was validated through comparison with CSIR wave data.

3.1 A comparison of wave height distribution at a virtual buoy and the nearest model grid point

The CSIR operates a real-time wave monitoring system in Table Bay which provides hourly updates of the wave conditions at the entrance channel off the port and also at a few other selected locations in the bay known as virtual buoys (Roussouw et. al. 2005). The system is based on wave data recorded at CSIR's Slangkop wave recording station which is then numerically simulated into Table Bay with the SWAN wave generation and refraction model. The model was calibrated with wave data measured by a Seapac wave recorder device which was deployed in Table Bay for 2 months.

In order to validate the results of the model developed for the resource assessment in Table Bay its output was compared to the data of the CSIR's virtual buoys which overlaps with the hindcast wave data for a 4 year period. An example of such a comparison is shown below in Figure 5 which is a plot of the model's significant wave height (H_s) data relative to the data of a virtual buoy, known as vt04. This data comparison, amongst others, proved that the model delivered results which are of an acceptable level of accuracy for the purposes of this study.

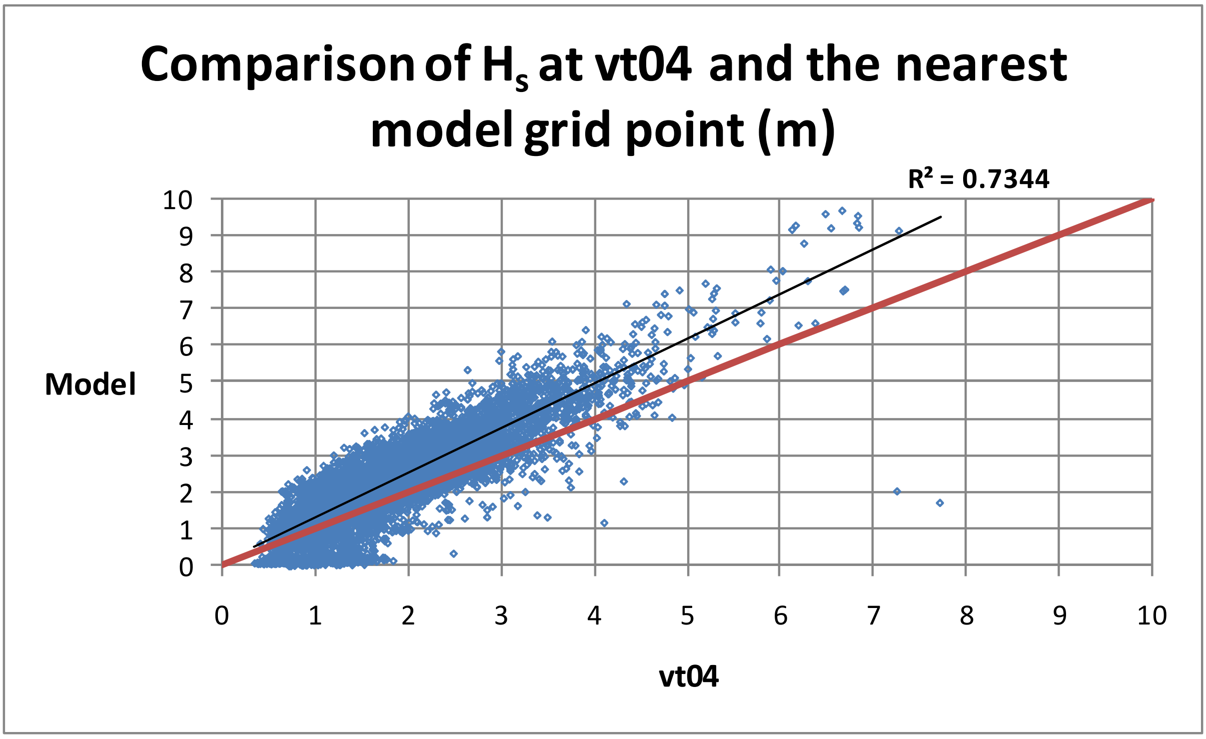

Figure 5: H_s comparison of the model and vt04

3.2 Granger Bay wave power resource

Statistical parameters of the mean monthly wave power at Granger Bay are shown below in Figure 6. It can be seen that Granger Bay has a low wave power resource due to its sheltered location, but could still be sufficient for the purposes of the ShoreSWEC. A 400 m ShoreSWEC breakwater could potentially have a generation capacity of 100 kW (assuming 25% efficiency).

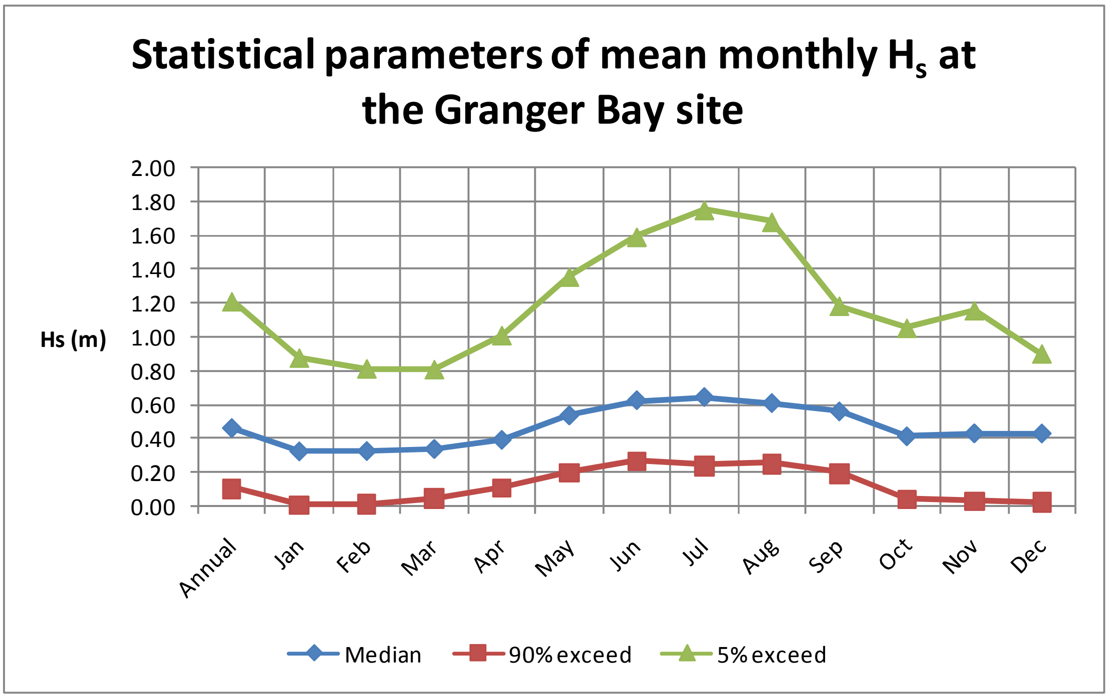

Figure 6: Statistical parameters of mean monthly H_s at the Granger Bay site

4 Conclusions and recommendations

Site selection criteria was developed and used to identify sites along the South African coast best suited for the deployment of the ShoreSWEC. Ganger Bay was identified as a promising site mainly due to the fact that a development was planned here that would require a caisson breakwater perfectly orientated to accommodate the deployment of the ShoreSWEC. A wave energy resource assessment was conducted to determine the available resource in Table Bay and specifically at Granger Bay. It was found that Granger Bay is exposed to low levels of wave power due to its sheltered location, but the site could still be suitable for the purposes of the ShoreSWEC. It is recommended that the design parameters of the ShoreSWEC be optimised through numerical and physical modelling. The device must also be designed for deployment at a generic location enhancing its suitability to a variety of sites. Once the design is complete and the generation capacity known, the economic feasibility of the ShoreSWEC must be assessed by means of an economic model.

Acknowledgements

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