

Techno-Commercial Study of Twin Unidirectional Turbine Based Wave Energy Plants

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ABSTRACT

Results from near-shore bottom standing Oscillating Water Column (OWC) based wave energy plants in Japan and India have now been available for about a decade. The most complete and detailed experimental results with near shore OWC plants are possibly from the one at Sakata port, Japan. Experience in Europe is mostly with shoreline devices as evidenced in the LIMPET and other similar plants. The plant in India is the longest standing device since its commissioning in 1991. It is unique in that several power modules with different turbines have been tested. Recently a proposal has been made to use twin unidirectional turbines in lieu of traditional bidirectional turbines promising very significant improvements in the power module efficiency. However, as experience has shown, the overall efficiency is also dependent on matching the power module to the OWC. In this work we review the principal design features that were initially considered for the Indian wave energy plant in the light of recent developments. We suggest methods for optimizing the overall performance in order to design the next generation OWC plant. The work will also be useful for planning newer installations. The influence of the power module on the overall efficiency will be clearly highlighted. As an example we estimate the performance of the Sakata port design with proposed twin unidirectional impulse turbines instead of twin 1.337 m Wells turbines using the experimentally observed hydrodynamic efficiencies. We show the performance of a wave energy plant designed for Indian conditions based on a comparison of the two designs for a plant with an overall width of 10m. The calculation is done for both monsoon and non monsoon conditions and the significant conclusions are highlighted. Cost estimates for two different plant sites, one island and one mainland, are also provided.

KEY WORDS: OWC, Indian wave energy plant, twin unidirectional turbine topology.

REVIEW OF INDIAN WAVE ENERGY PROGRAM

The Indian Wave Energy plant at Vizhinjam, Kerala is a bottom standing near shore OWC based plant with a 10 m opening width. The uniqueness of the plant lies in the fact that several conceptually different power modules were tested in the same caisson constructed in December 1990. Initially, the plant was designed with a 2m diameter Wells turbine and a 110 kW squirrel cage induction generator. The plant was not completely characterized due to insufficient instrumentation. The squirrel cage induction generator had

a limited speed variation of up to 8% of synchronous speed. The vertical axis assembly of the power module also posed a lot of operational and maintenance problems. The next module was a twin 1m Wells turbine with a 55 kW slip ring induction generator. Improvements were now made in the choice of instrumentation and data acquisition. However the size of the turbine was insufficient to handle the full plant capacity. Finally, a 1m linked guide vane impulse turbine with the same induction generator was tested. This resulted in larger turbine size, but reduced hydro dynamic efficiency because of the different damping characteristics (Ravindran, 1997).

RECOMMENDATIONS FOR A NEW TOPOLOGY FOR THE POWER MODULE

The wave to wire efficiency of an OWC based plant is given by

$$EFF_{atg} = EFF_a \times EFF_t \times EFF_g \quad (1)$$

where

$$EFF_a = \frac{\text{Pneumatic Power}}{\text{Wave Power}}, \text{ the OWC efficiency}$$

$$EFF_t = \frac{\text{Turbine Power}}{\text{Pneumatic Power}}, \text{ the turbine efficiency}$$

$$EFF_g = \frac{\text{Electrical Power}}{\text{Turbine Power}}, \text{ the electrical generator efficiency}$$

However, as experience has shown, the overall efficiency is also dependent on matching the power module to the OWC. The OWC efficiency is dependent on the damping of the succeeding power module. The turbine efficiency is a non linear function of the flow coefficient which in turn is affected by the speed variations of the coupled electrical generator. Practical measurements (Ohno, 1993) have shown that it is possible to attain OWC efficiencies greater than 90% with optimum damping. At higher power levels, the efficiency of an electrical generator can also be 90% over a wide range of inputs (Ohno, 1993). Thus, the component with the lowest efficiency is the turbine.